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Lewis Safety Manual

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LEWIS SAFETY MANUAL

SAFETY POLICY

It is the policy of the Lewis Research Center, herein defined as the Cleveland Center and the Plum Brook Station, to manage and conduct its research and development operations in such a manner as to eliminate or minimize all potential hazards and to avoid accidents involving injury to personnel, damage to property, or loss of research operating time and effectiveness. In addition it is our policy to eliminate pollution to the atmosphere, ground water, or land and to minimize potential exposure to hazardous materials. The Lewis Research Center will follow all applicable Federal, State, local, and contractual laws and regulations affecting the safety and health of its employees. In addition, the Center will adhere to recognized pollution standards, safety codes, regulations, and standards based on the dictates of **sound engineering judgment** in all institutional and R&D operations and activities, including the modification or construction of facilities.

The review, approval, and surveillance functions of the Lewis Safety Organization (Executive Safety Board, Area Safety Committees, and panels) have been established to ensure compliance with good engineering safety practices. Nevertheless, all Lewis employees are charged with personal responsibility for constant adherence to safety procedures and safe practices. Each employee must take an active interest in the Lewis Safety Program that has been established and must take responsibility for following the rules and regulations set forth in this Manual. To achieve and maintain a safe working environment requires the positive coöperation of both the employee and the Center. All visitors and contractors shall also be required to adhere to all safety requirements contained in this Manual.

This Safety Manual is an up-to-date compilation of policies, procedures, proven experiences, and recommended safety practices for pertinent Lewis Research Center operations. Note that the technical material and recommendations contained herein represent **minimum** standards and practices for the specialized topics being considered. Where appropriate, other acceptable standards and codes will simply be cross-referenced. Proposed deviations from these procedures and recommendations must be examined critically and must be brought to the attention of the cognizant Safety Committee for detailed assessment and concurrence prior to implementation. Significant deviations will require review and approval by the Executive Safety Board. In every case, sound engineering is to prevail. As new technical information is generated or becomes available, it will be added to this Manual if appropriate to Lewis Research Center efforts. In this way, safe designs and operations will evolve from the best possible base of knowledge and engineering criteria, thereby resulting in sound risk management.

APPLICABILITY OF MANUAL

The Lewis Safety Manual applies to all Cleveland and Plum Brook Station facilities, equipment, technical operations, and personnel (employees, contractors, and visitors) and intends to address organizational elements and personnel in offsite operations as described herein.

If an operation is conducted at the site of or in the facilities of another NASA center or Government agency, or in their aircraft or vessels, the safety requirements and approval procedures of the host center or agency shall govern and are to be complied with. The Lewis employee in charge must take action on his or her own initiative to ascertain the host organization's safety requirements approval procedures and must see that they are fulfilled. The Safety Assurance Office (SAO) is available to aid and support the offsite operation safety requirements.

If Lewis personnel conduct an offsite operation where there is no host organization, or the host organization has no formal procedures in effect for safety approval, or the host organization places all or part of the responsibility for the safety approval process on Lewis, then the operation shall be subject to the same rules and regulations set forth in this Manual for onsite operations. All such offsite operations shall require that a Safety Permit Request be prepared in accordance with Chapter 1 of this Manual, and that it be submitted to the Chief of the SAO for appropriate safety review and approval.

S.V. Szabo, Chairman
Executive Safety Board

L.J. Ross, Director
Lewis Research Center

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IN CASE OF FIRE, ACCIDENT, OR EMERGENCY, CALL 911

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Chapter 1. LEWIS SAFETY MANAGEMENT AND THE SAFETY PERMIT SYSTEM

1.1 PROGRAM

1.1.1 Scope

The Lewis Safety Management Program includes a Centerwide Lewis Safety Organization that provides the technical expertise and the safety orientation necessary to execute the Program functions and responsibilities; a safety control and accident reporting system that handles all the potential hazards known to exist at Lewis; a safety education and training system; and a Lewis safety publication.

1.1.2 Applicability

The instructions of the Lewis Safety Management Program apply to the Cleveland Center and the Plum Brook Station.

1.1.3 Authority

The authority for the Program is derived from the "NASA Basic Safety Manual" (NHB–1700.1, Vol. 1–B).

1.1.4 Policy

It is Lewis policy to administer its operations so as to reduce or eliminate all potential hazards, thereby avoiding undue risk and accidents that can result in loss of life, injury to personnel, damage to property, or loss of research operating time and effectiveness. To this end, a definite, comprehensive Safety Management Program encompassing every applicable phase of Center activity shall be established and implemented. Using the dictates of sound engineering judgment, Lewis will follow recognized safety codes and standards in all operations, including the modification or construction of facilities.

1.1.5 General Considerations

The Lewis Safety Management Program must consider both the Lewis safety environment and basic safety management.

<u>The Lewis safety environment</u>.—Safety considerations at the Center are many and complex as a result of the following:

(a) The diversity of R&D operations in propulsion, power, and energy-related research

(b) The potentially hazardous character of the materials, fluids, test equipment, and processes involved

(c) The continual turnover of experiments and the constantly changing nature of research test operations

(d) The range and depth of the technical competence that is required to manage a safety program in such an environment

Basic safety management.—For effective operation, Center safety management must provide

(a) The means of identifying, locating, and eliminating or controlling all potential hazards known to exist at Lewis

(b) The means of establishing and maintaining such employee safety data as specific hazard exposure, training, medical examinations, accident reports, and so on

(c) General compliance with "Occupational Safety and Health Administration (OSHA) Standards" (29 CFR).

(d) The means of integrating all of these into a coordinated Centerwide safety operations plan

1.1.6 Basic Responsibilities

Lewis Director.—The Center Director is responsible for the establishment of a Lewis Safety and Accident Prevention Program in accordance with federal regulations, the "NASA Basic Safety Manual," NHB–1700.1, Vol. 1–B, and other related guidelines set up by NASA Headquarters.

Lewis Safety Organization.—The Lewis Safety Organization includes the Executive Safety Board; the Safety Assurance Office; Area Safety Committees; the Aviation Safety Officer; the Electrical Applications and the Process Systems Safety Committees; Plum Brook Reactor Facility Safety Committee; the Office of Health Services; the Office of Environmental Programs, including the Radiation Safety Committee and the Industrial Hygiene Office; and the Environmental Pollution Control Board. It is broadly responsible for

(a) Promulgating Lewis safety policies and developing an effective Safety Management Program, including definition and implementation of the Center safety and accident prevention plan

(b) Evaluating Program effectiveness

(c) Developing appropriate recommendations and corrective actions to improve Program effectiveness

(d) Establishing and/or approving in-house safety standards, regulations, and criteria, and reviewing and monitoring operational compliance therewith

(e) Reviewing installations and equipment and issuing Safety Permits to operate facilities

Chief of the Safety Assurance Office.—The Chief of the Safety Assurance Office (SAO) is responsible for the overall management, coordination, and documentation of the Lewis Safety Management Program and, in conjunction with the ESB, for the implementation of Center safety policies and directives. The SAO Chief also serves as the Center focal point of communications on all safety matters and on functional safety relationships between the Center and NASA Headquarters.

Supervisors.—All organization supervisors have a prime responsibility for compliance with pertinent safety requirements (including those related to housekeeping and shop safety) and for ensuring the effectiveness of the Lewis Safety Management Program as it affects their specific activities. This responsibility includes, but is not limited to, the following:

(a) Knowing pertinent Lewis safety requirements; communicating these requirements to subordinate personnel; mandating compliance with these requirements; and **monitoring** this compliance

(b) Knowing about and ensuring adherence to Lewis safety approval procedures

(c) Reviewing the work proposals of subordinates to ensure that all potential hazards are properly identified and evaluated, that procedures for safe operation and effective emergency rescue have been developed, and that the cognizant Area Safety Committee evaluation is obtained

(d) Personally surveying their work areas and recognizing potential hazards therein; analyzing statistics on accidents and near accidents in these areas; and initiating or recommending corrective action where required

(e) Supplying the Safety Assurance Office with the necessary technical input for the development of safe operating procedures, emergency rescue procedures, or any other safety documentation deemed necessary by the Safety Assurance Office

(f) Providing direction for continuing safety education and training for subordinate personnel in accordance with the standards and criteria established by the Safety Assurance Office

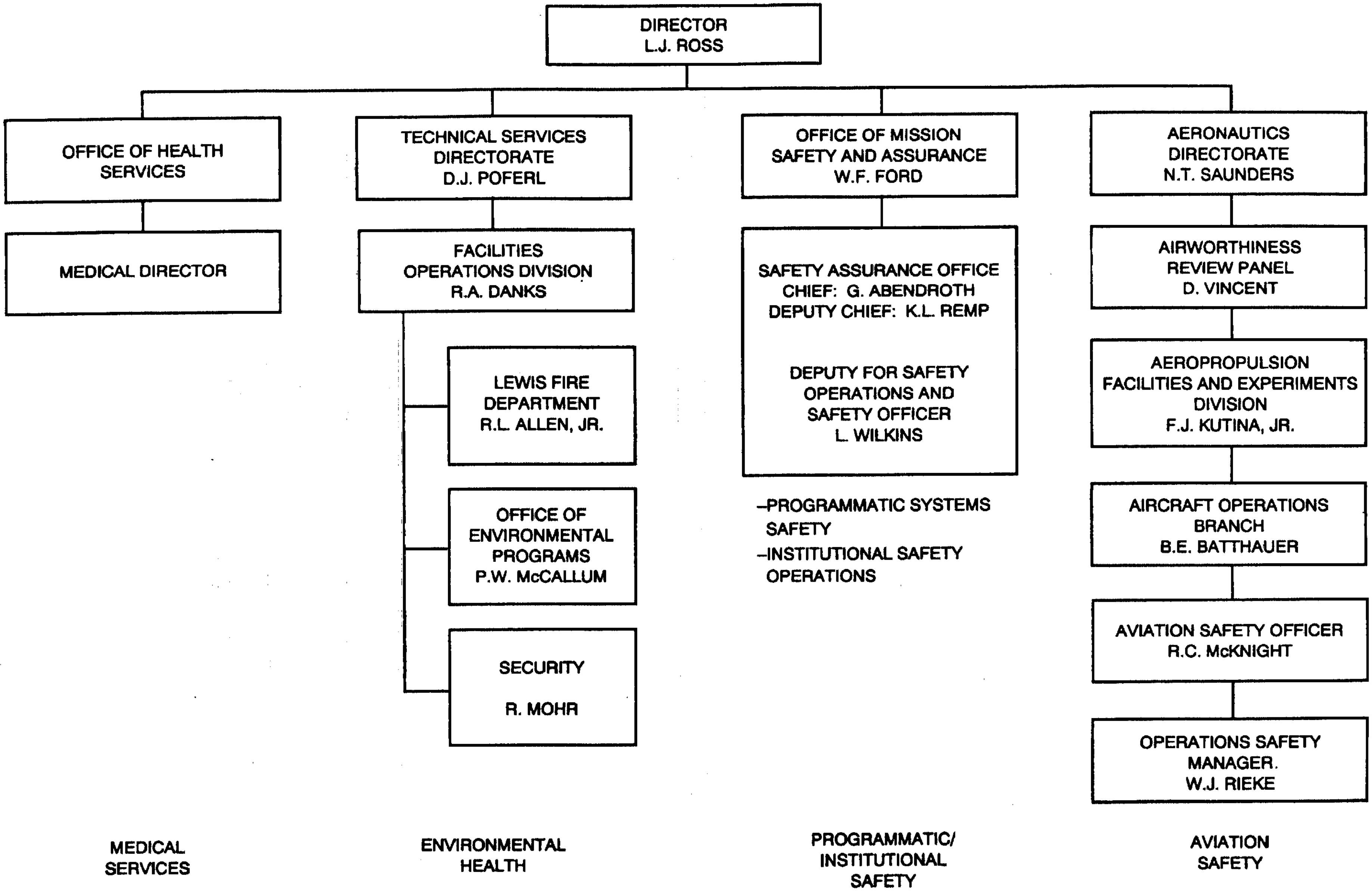
Employees.—Each Lewis employee is responsible for

(a) Exercising reasonable care and caution in the safe performance of his or her work assignments and in the conduct of any activity at the Center

(b) Possessing knowledge of Lewis safety regulations, safe operating procedures, and emergency rescue procedures affecting his or her individual work area and work assignments and complying therewith

(c) Reporting the development or appearance of any potentially hazardous condition to his or her supervisor, to the Division Safety Representative, to the Safety Assurance Office, or to the Area Safety Committee chairman

LEWIS SAFETY ORGANIZATIONAL ELEMENTS



1.1.7 Operating Responsibilities and Procedures

The specific operating responsibilities, procedures, and related requirements for the implementation of the Safety Management Program are reflected in the chapters of this Manual.

1.2 LEWIS SAFETY ORGANIZATION

1.2.1 Scope

The Lewis Safety Organization includes the Executive Safety Board; the Safety Assurance Office; Area Safety Committees; the Aviation Safety Officer; the Electrical Applications and the Process Systems Safety Committees; Plum Brook Reactor Facility Safety Committee; the Office of Health Services; the Office of Environmental Programs, including the Radiation Safety Committee and the Industrial Hygiene Office; and the Environmental Pollution Control Board.

The responsibilities and authorities of the Lewis Safety Organization are described in subsequent paragraphs.

1.2.2 Applicability

The Lewis Safety Organization directives apply to the Cleveland Center and the Plum Brook Station.

1.2.3 Authority

The authority for this organization comes from the "NASA Basic Safety Manual," NHB 1700.1, Vol. 1–B, and the "NASA Safety and Health Handbook," NHB 2710.1.

1.2.4 Objectives

The Lewis Safety Organization is structured to

(a) Ensure a safe work environment for conducting Lewis operations

(b) Avoid loss of life, injury of personnel, damage to or loss of property, and disruption of operations

(c) Ensure that an organized and systematic approach is used to identify and control potential safety hazards

(d) Obtain thorough and timely safety reviews and approvals for all technical operations at Lewis

(e) Instill safety awareness in all Lewis employees

(f) Provide specialized technical knowledge essential to continuing safety maintenance on a Centerwide basis

1.2.5 Executive Safety Board

The Executive Safety Board (ESB) serves as the Center's safety policy- and decision-making board and is responsible for the overall direction of the Lewis Safety Program. The ESB reports to the Center Director and is responsible for ensuring that all aspects of safety at Lewis are properly addressed and that the objectives of the program are met. The Center Deputy Director or his appointee serves as chairman of the ESB.

Responsibilities.—The responsibilities of the ESB are to

(a) Establish a system of safety committees, advisory panels, and investigating committees to conduct detailed third-party reviews of specified Lewis operations and take necessary action to ensure safe operations within the limits of prescribed authority

(b) Oversee and monitor the activities of the committees and panels comprising the Lewis Safety Organization to ensure that they are appropriately staffed and operating

(c) Establish (or abolish) committees and panels and use consultants and experts as deemed necessary

(d) Report to the Center Director at least annually, providing a summary of the principal activities of the Lewis Safety Organization that includes an evaluation of its accomplishments and progress and an identification of problems or other matters requiring the attention of Lewis management

(e) Review, evaluate, and resolve any disputes on safety matters referred to it by any of the subdivisions of the Lewis Safety Organization

(f) Refer to the Director any Center safety disputes felt to warrant his attention and decision; acquaint the Director with significant major risks, for his concurrence about acceptability; ensure that such referrals include at least the following information: background, principal issues involved, pros and cons from a safety standpoint, hazard or risk analysis, and the Board's final evaluation and recommendation

(g) Provide policy and technical direction to the Lewis Safety Director to ensure uniformity and consistency of safety operations throughout Lewis

(h) Meet at the call of the chairman

Authority.—In addition to the authority implicit in performing the functions and responsibilities described in Section 1.2.5, the ESB or any member thereof has the authority to stop and forbid any operation about which there is a safety concern, until an appropriate review and determination can be made. Exercise of this authority requires immediate notification to the chairman of the ESB and the chairman of the Area Safety Committee involved. The ESB has the authority to overrule any subordinate Lewis Safety Organization element except where Nuclear Regulatory Commission requirements are involved.

1.2.6 Lewis Safety Assurance Office

Chief of the Safety Assurance Office.—The primary function of the Chief of the SAO is to implement, manage, and coordinate the Lewis Safety Program through his/her staff, which includes the Lewis Safety Officer, and the various committees. The Chief of the SAO reports on the overall Lewis Safety Program to the Executive Safety Board. The staff supporting the SAO Chief shall provide competent engineering judgment and analysis in executing safety policy and responsibility.

Responsibilities: The responsibilities of the Chief of the SAO are to

(a) Implement safety policies formulated by the Executive Safety Board (ESB) and perform those safety functions required by this Manual and other applicable regulations and directives

(b) Manage, implement, coordinate, and review the Lewis Safety Permit program

(c) Serve as consultant on safety matters to Lewis senior staff and management

(d) Assist the Lewis Procurement Officer in determining the adequacy of contractor safety programs and approve the content and the scope of the programs

(e) Maintain the Lewis Safety Manual and ensure that drafts of all proposed chapters for the Manual are distributed to the members of the ESB and the Environmental Pollution Control Board, and to the chairmen of cognizant safety committees and advisory panels, for review before publication

(f) Ensure that all material to be included in the Lewis Safety Manual has received prior written approval of the ESB and of the chairman of the Environmental Pollution Control Board, as appropriate

(g) Serve as the executive secretary to the ESB and as an ex-officio member of all safety committees and those investigating committees and advisory panels associated with the ESB

Authority: The Chief of the SAO has the authority to terminate any operation of questionable safety until an appropriate review and determination can be made. Exercise of this authority requires immediate notification to both the chairman of the ESB and the chairman of the Area Safety Committee involved

Lewis Safety Officer.—The Lewis Safety Officer ensures proper implementation of safety operations throughout the Center. The Lewis Safety Officer reports to and receives technical direction from the Chief of the SAO.

Responsibilities: The responsibilities of the Lewis Safety Officer are to

(a) Implement safety policies and perform those safety functions required by this Manual and other applicable regulations and directives

(b) Administer the expiration notification process for the Lewis Safety Permit program

(c) Maintain a safety information library containing codes, manuals, handbooks, the hazards inventory, information files, records, and references

(d) Monitor, through safety staff, contractor activities onsite to ensure compliance with all applicable safety standards and regulations

(e) Keep illness and injury records in accordance with OSHA regulations and prepare quarterly and annual reports to the Department of Labor and other relevant government agencies

(f) Manage, and coordinate with the Lewis Fire Department and Security Branch, emergency responses to Center accidents and mishaps

Authority: The Lewis Safety Officer has the authority to shut down any operation of questionable safety, until an appropriate review and determination can be made. Exercise of this authority requires immediate notification to the Chief of the SAO, the chairman of the ESB and the chairman of the Area Safety Committee involved.

1.2.7 Aviation Safety Officer

The Lewis general safety program concerned with airworthiness and flight safety is implemented by the Aviation Safety Officer (ASO). This officer participates with the Area 1 Safety Committee in the review of Safety Permit Requests for proposed operations involving flight research and program support aircraft assigned to Lewis. The ASO also serves as an ex-officio member of the Area 1 Safety Committee.

Responsibilities.—The responsibilities of the ASO are to

(a) Review and evaluate proposed modifications to Lewis aircraft and the aircraft assigned to support Lewis programs, and review and evaluate operating procedures, performance requirements, and restrictions for missions on these aircraft

> NOTE: The term "modification" refers to any alteration, addition, or removal of aircraft structure, components, equipment, or instrumentation, including equipment or instrumentation used for research purposes. The term "mission" refers to any flight of Lewis aircraft or aircraft assigned to support Lewis programs.

(b) Provide technical guidance on safety aspects of flight programs

(c) Maintain surveillance of aviation activities for conformance with prescribed directives, standards, procedures, and Safety Permit (NASA Form C-919) restrictions, and initiate corrective action when required

(d) Review aviation training and assess personnel qualifications to ensure safety of operations

(e) Review and countersign those Safety Permit forms issued by the Area 1 Safety Committee that involve Lewis aircraft and aircraft assigned to support Lewis programs

(f) Review and approve Flight Work Order forms (NASA Form C-500) as required

(g) Report to the ESB at designated meetings

Authority.—In addition to the authority necessary to implement assigned responsibilities, the ASO has the authority to shut down any operation or activity on which there is a question of aircraft flight safety, until an appropriate technical review can be conducted. Exercise of this authority requires immediate notification to the chairman of the ESB, the chairman of the Area 1 Safety Committee, and the Chief of the SAO.

1.2.8 Process Systems Safety Committee

The Process Systems Safety Committee (PSSC) ensures that the central service systems of the Center are designed to, and in fact do, operate in a safe manner. Central service systems include the systems and equipment for conveying, supplying, generating, removing, distributing, or processing liquids and gases and the prime machinery for each process system leading to and terminating at the test cell or an area of a research setup.

NOTE: The following systems are specifically included: central air and exhaust systems, fire and domestic water systems, carbon dioxide systems, steam systems, natural gas systems, heating plants, cooling tower water systems, cooling towers, wet and dry coolers, industrial waste basins and the lines leading to them, general purpose and mobile cryogenic equipment, pressure vessels and related systems, and the Engine Component Research Laboratory underground fuel storage and distribution system.

Responsibilities.—In order to ensure the safe operation of the central service systems of the Center, the Process Systems Safety Committee has been charged with the following specific responsibilities:

(a) Establish acceptable safety standards and review specific proposals for modifications or additions to facilities, equipment, or operations involving process systems

(b) Oversee application of NHB 1700.6, "Guide for Inservice Inspection of Ground-Based Pressure Vessels and Systems"

(c) Approve and issue the Safety Permit for those proposals that meet Lewis safety requirements

(d) Supply the cognizant Area Safety Committee chairman with copies of the Safety Permits issued by the PSSC, calling attention to approved modes or levels of operation of the central systems so that Area Safety Committees do not approve research operations exceeding authorized bounds (Conversely, Area Safety Committees and Safety Permit requestors are expected to notify the PSSC of activities that are likely to affect the process systems.)

(e) Recommend, subject to the review and approval of the Executive Safety Board (ESB), minimum acceptable safety standards within the scope of the functions set forth in Section 1.2.8

(f) Advise Area Safety Committees and other organizational elements, upon request, about the safety aspects of specific proposals involving process systems

(g) Maintain technical surveillance of and keep informed of current activities in assigned area of responsibility, to anticipate problems and minimize safety-related conflicts between organizational elements

(h) Submit to the ESB significant concerns or unresolved questions regarding the granting of permits and the assessment of major risks

(i) Report, through the Committee chairman, to the ESB at its designated meetings

Authority.—In addition to the authority necessary to implement the Committee's assigned responsibilities, the chairman of the Process Systems Safety Committee has the authority to shut down any operation or activity on which there is a question of process systems safety, until an appropriate technical review can be conducted. Exercise of this authority requires immediate notification to the chairman of the ESB, the chairman of the Area Safety Committee concerned, and the Chief of the SAO.

1.2.9 Electrical Applications Safety Committee

The Electrical Applications Safety Committee reviews all major electrical power systems leading to facility test cells or research setups and issues the Safety Permit to cover activities that cross safety area boundaries. The prime safety responsibility of the Committee is the power distribution system, including all substations, power transformers, and switchgear rated at 2400 volts or higher. For systems of 480 volts or less that lead to facility test cells or research setups, the power system interface is at the main distribution panels. The Committee is charged also with reviewing novel electrical applications. It provides copies of its Safety Permit forms to cognizant Area Safety Committees and ensures that Area Safety Committees do not approve research operations exceeding authorized bounds. As with the Process Systems Safety Committee (see Sec. 1.2.8), Area Safety Committees and originators of a Safety Permit Request are expected to notify the Electrical Applications Safety Committee when proposals are likely to impact the safety of electrical power systems.

Responsibilities.—Specific responsibilities of the Electrical Applications Safety Committee are to

(a) Review specific proposals for the design, construction, alteration, or removal of electrical power systems or special electrical applications, and approve and issue a Safety Permit for those proposals that meet Lewis safety requirements

(b) Recommend, subject to review and approval of the ESB, minimum acceptable safety standards within the scope of the functions set forth in Section 1.2.9

(c) Advise Area Safety Committees, the Process Systems Safety Committee, and other organizational elements, upon request, about the safety aspects of specific proposals involving electrical applications

(d) Maintain technical surveillance of and keep informed of activities in assigned area of responsibility, to anticipate problems and minimize safety-related conflicts between organizational elements

(e) Submit to the ESB significant concerns or unresolved questions regarding the granting of permits and the assessment of major risk

(f) Report, through the Committee chairman, to the ESB at its designated meetings

Authority.—In addition to the authority necessary to implement the Committee's assigned responsibilities, the chairman of the Electrical Applications Safety Committee has the authority to shut down any operation or activity on which there is a question of electrical power systems safety, until an appropriate technical review can be conducted. Exercise of this authority requires immediate notification to the chairman of the ESB, the chairman of the Area Safety Committee concerned, and the Chief of the SAO.

1.2.10 Plum Brook Reactor Facility Safety Committee

The Plumb Brook Reactor Facility Safety Committee ensures compliance with the Nuclear Regulatory Commission (NRC) licenses for the Plum Brook Reactor Facility (PBRF) and the Mockup Reactor contained within the PBRF. The current licenses, which expire in 1997, define a condition to possess-but-not-operate. The PBRF Safety Committee reviews all matters with safety implications, to ensure that plans, technical specifications, safety analyses, the radiator safety program, and written procedures provide protection to the worker, the facility, and the environment. In addition, it ensures that activities authorized under the license are conducted without endangering the health and safety of the public. The Committee concerns itself with radiation safety, industrial hygiene, and industrial safety; minimizing public and employee radiation exposure is a prime consideration. The Committee consists of four or more members, at least one of which shall have a nuclear background and one a familiarity with the conditions of the facility. The Radiation Safety Officer shall also be a member.

Responsibilities.—The Plum Brook Reactor Facility Safety Committee responsibilities are to

(a) Approve new and revised PBRF procedures and facility changes that have safety implications, thereby ensuring that such procedures and changes are safe and consistent with NRC licenses and regulations

(b) Review any license change request prior to submitting it to the NRC

(c) Conduct periodic reviews and inspections of activities and records, to determine if the radiation controls and other safety controls required at the PBRF are being met

(d) Review and approve corrective actions that are proposed to preclude repetition of incidents, malfunctions, and personnel errors affecting facility safety

(e) Maintain technical surveillance of and keep informed of current activities at the PBRF, to anticipate safety-related problems

(f) Approve the method to control and maintain inventories of radioactive materials procured and disposed of

(g) Provide review, surveillance, and guidance as directed by the charter of the Committee

(h) Submit to the ESB significant concerns or unresolved questions regarding the granting of permits and the assessment of major risks

(i) Report, through the Committee chairman, to the ESB at its designated meetings

Authority.—In addition to the authority necessary to implement the Committee's assigned responsibilities, the chairman of the Plum Brook Reactor Facility Safety Committee has the authority to shut down any operation or activity on which there is a question of safety, until an appropriate technical review can be made. Exercise of this authority requires immediate notification to the chairman of the ESB and the Chief of the SAO.

1.2.11 Area Safety Committees

The Area Safety Committees conduct third-party reviews of all proposed installations and operations in their assigned areas to ensure that the proposed design and/or operation is consistent with the dictates of sound engineering judgment and acceptable health and safety standards. (Safety areas of the Cleveland Center and the Plum Brook Station are shown in the Lewis Telephone Directory.)

Responsibilities.—Area Safety Committee responsibilities are to

(a) Review specific proposals for all research operations, for modifications or additions to facilities and equipment, or for any project that may affect safety within the assigned safety areas

(b) Approve and issue permits for those proposals that meet Lewis safety requirements as prescribed in Section 1.5.5, Forms and Rules

(c) Maintain technical surveillance of and keep informed of current activities in assigned area of responsibility to anticipate problems and minimize safety-related conflicts between organizational elements

(d) Recommend, subject to the review and approval of the ESB, minimum acceptable safety standards within the scope of the functions set forth in Section 1.2.11

(e) Obtain comments and advice from advisory panels, the Safety Assurance Office, and the Office of Environmental Programs concerning matters that fall within their areas of specialization

(f) Make periodic surveys (at least annually) of plant and research operations within assigned areas and report results thereof to the Chief of the SAO

(g) Ensure that activities presenting significant risk to persons or property have a formal readiness review by the requester's line management prior to issuing a Safety Permit

(h) Submit to the ESB significant concerns or unresolved questions regarding the granting of permits and the assessment of major risks

(i) Report, through the Committee chairman, to the ESB at designated meetings

Specific committees' responsibilities.—Besides the responsibilities set forth in Section 1.2.11, the following responsibilities apply to specific committees:

Area 1 Safety Committee: This Committee issues the required Safety Permit to cover all operations, maintenance, and R&D modifications of Lewis aircraft or other aircraft operated in support of Lewis programs and requiring the presence of Lewis personnel. The safety review, which also includes equipment and systems to be flown onboard, is always performed in collaboration with members of the Airworthiness Review Panel. Before issuing a Safety Permit, the Committee routes it to the Aviation Safety Officer for review and concurrence.

Area 6 Safety Committee: In implementing its responsibilities, this Committee coordinates with the Radiation Safety Committee, which has specific responsibilities to the Nuclear Regulatory Commission (NRC) in meeting established NRC requirements.

Area 9 Safety Committee: This Committee is responsible for all of the Plum Brook Station except the Plum Brook Reactor Facility, which is under cognizance of the PBRF Safety Committee.

Authority.—In addition to the authority necessary to implement the Committee's assigned responsibilities, the chairman of each Area Safety Committee has the authority to shut down any operation or activity in the assigned area on which there is a question of safety, until an appropriate technical review can be made. Exercise of this authority requires immediate notification to the chairman of the ESB and the Chief of the SAO.

1.2.12 Office of Health Services

For the protection of employees Lewis maintains a comprehensive occupational medicine program under the direction of the Lewis Medical Director. Services provided under the program include investigation of the medical aspects of personal injury cases, medical diagnosis and treatment of occupational injuries, first aid, a physical fitness program, and the Health Screening Clinic. The responsibilities of the Office of Health Services are described in Section 1.4, Lewis Occupational Medicine Program.

1.2.13 Office of Environmental Programs

The Office of Environmental Programs is responsible for the recognition, measurement, and recommended control of hazardous factors in the work environment that can cause illness, disease, or impaired well-being. The Office of Environmental Programs serves as consultant to the Lewis staff on matters of environmental quality, industrial hygiene, and health physics (including radiation safety). The responsibilities of the Office of Environmental Programs are described in Section 1.3.8.

1.3 LEWIS ENVIRONMENTAL QUALITY ORGANIZATION

1.3.1 Scope

The Lewis Environmental Quality Organization includes the Environmental Pollution Control Board (EPCB), the Office of Health Services, the Office of Environmental Programs (OEP), and the Radiation Safety Committee (RSC).

The responsibilities and authority of the Environmental Quality Organization are described in the following paragraphs.

1.3.2 Applicability

The provisions listed herein are applicable to the Cleveland Center and the Plum Brook Station.

1.3.3 Authority

The authority of the Lewis Environmental Quality Organization comes from NHB 8800.11, "Implementing the Provisions of the National Environmental Policy Act"; "The Occupational Safety and Health Act (1970)," Section 19; Executive Order 11514, "Protection and Enhancement of Environmental Quality"; Executive Order 12196, "Occupational Safety and Health Programs for Federal Employees"; Executive Order 12088, "Federal Compliance with Pollution Control Standards"; Executive Order 11752, "Prevention, Control, and Abatement of Environmental Pollution at Federal Facilities"; and the "NASA Basic Safety Manual," NHB 1700.1 (Vol. 1–B).

1.3.4 Objectives

The Lewis Environmental Quality Organization is structured to

(a) Instill environmental awareness in all Lewis employees

(b) Provide specialized technical knowledge essential to continuing protection and enhancement of environmental quality on a Centerwide basis

(c) Maintain control over potential environmental hazards, consistent with pertinent environmental standards and guidelines and sound engineering and operating practices

(d) Provide Lewis management with a centralized source of information on matters of environmental quality and control

1.3.5. Policy

It is Lewis policy to operate in a manner that provides a safe and healthful workplace for employees; that complies with all laws and regulations pertaining to health and the environment; and that protects and enhances the surrounding community and the environment, consistent with the mission of the Center.

Responsibility for implementing this policy lies with line management and all employees. The Environmental Quality Organization is responsible for providing guidance and oversight of implementation and for making periodic reports to regulatory agencies and others. Line management must ensure that operations under its control are operated consistent with these instructions and guidance from the Environmental Quality Organization.

1.3.6 Environmental Pollution Control Board

The Lewis Environmental Pollution Control Board serves as the Center environmental policy- and decision-making board. It is responsible for the overall direction of the Lewis Environmental Quality Organization. The Board is responsible for assuring the Center Director that all aspects of environmental quality are properly addressed and that program objectives are met.

Responsibilities.—Specific responsibilities of the Board are to

(a) Recommend, to the Center Director, policies and practices for improvement in environmental health

(b) Provide environmental policy and direction to the Chief of the Office of Environmental Programs

(c) Coordinate with the Lewis Safety Organization to ensure third-party functional review of all Lewis R&D activities

(d) Serve as an appeal channel on unresolved questions pertaining to the environmental sensitivity of Lewis operations, and review, evaluate, and resolve any disputes

(e) Review existing or potential environmental problems and submit to the Center Director, along with the Board's evaluation and recommendations, any disputes that warrant the Director's attention and decision

(f) Develop systematic procedures to ensure a timely transfer of information and an understanding of programs affecting the environment, taking alternative courses of action into consideration

(g) Ensure that information about existing or potential environmental problems is made available to all appropriate levels of Lewis management

(h) Review NASA regulations, policies, and procedures relating to environmental pollution control and inform the Center Director of any Lewis operational deficiencies or inconsistencies therewith

(i) Review environmental impact assessments and statements related to Lewis operations; transmit assessments or statements with applicable recommendations to the cognizant NASA Headquarters organization

(j) Exchange pollution control data and research results with other Governmental agencies

(k) Meet quarterly, or as otherwise necessary, and submit to the Director a written report of the results of the meetings

Authority.—In addition to the authority necessary to ensure performance of its stated responsibilities, the Environmental Pollution Control Board, or any member thereof, has the authority to close down any operation having a serious negative impact on the environment, until an appropriate review and assessment can be made. Exercise of this authority requires immediate notification to the chairman of the Environmental Pollution Control Board, the Chief of the Office of Environmental Programs, the chairman of the Area Safety Committee having jurisdiction in the area involved, and the chairman of the Executive Safety Board.

1.3.7 Office of Health Services

For the protection of employees, Lewis maintains a comprehensive occupational health program under the direction of the Lewis Medical Officer. This program provides investigation of the medical aspects of personal injury cases, medical diagnosis and treatment of occupational injuries, a physical fitness program, health screening clinic, and first aid. The Lewis Medical Officer serves as a member of the Environmental Pollution Control Board. The responsibilities of the Office of Health Services are described in LMI 1800.1, as revised, "Lewis Occupational Medicine Program," and Section 1.4.5 herein.

1.3.8 Office of Environmental Programs

The Office of Environmental Programs (OEP) is responsible for recognizing, measuring, and recommending control of hazards in the work environment that can cause illness, disease, or impaired well-being. The OEP serves as a consultant to the Lewis staff on matters of environmental quality, industrial hygiene, and health physics, and ensures compliance in these areas.

Responsibilities.—The responsibilities of the OEP are to

(a) Implement policies formulated by the Environmental Pollution Control Board

(b) Maintain appropriate handbooks, information files, and references, and serve as consultant on environmental quality, industrial hygiene, and radiation safety matters to the Lewis staff

(c) Assist the Lewis Procurement Officer in reviewing the environmental quality programs of contractors

(d) Make surveys of work areas on a periodic basis, collect samples associated with potentially toxic or other environmental hazards, and coordinate these efforts with cognizant personnel in the required technical specialties

(e) Advise Area Safety Committees (1) on the pollution control aspects of specific proposals to install, remove, or alter waterborne waste disposal facilities or air pollution control equipment in their areas; and (2) on the industrial hygiene aspects of specific proposals to install, remove, or alter systems, equipment, or operations

(f) Review requests for a Safety Permit to determine whether such requests concern matters under the cognizance of the Office, and when necessary, coordinate with Area Safety Committees in third-party reviews of proposed activities

(g) Review the precautions taken by operating officials with respect to controlling the acquisition of unusually toxic or radioactive materials; supervising the distribution, use, accountability, and disposal of toxic or radioactive materials; disposing of waterborne wastes through the various Lewis sewer systems; discharging exhaust, vent, or waste gases into the atmosphere; and monitoring systems designed to safeguard the health of persons associated with sources of pollution or exposed to toxic materials

(h) Evaluate these precautions, report to the Environmental Pollution Control Board on their effectiveness, and recommend changes if necessary

(i) Recommend, subject to review and approval by the Environmental Pollution Control Board, minimum acceptable environmental quality standards for operations involving toxic and noxious materials and pollution sources

(j) Request special experiments and investigations to delineate potential environmental hazards and evaluate the proposed methods of their control

(k) Verify compliance throughout Lewis with all pertinent regulations applicable to the prevention, control, and abatement of air and water pollution

(l) Keep abreast of developments and requirements in the fields of industrial hygiene, air and water pollution control, and health physics

(m) Review each Purchase Request for chemicals and hazardous materials, evaluate the hazard potential for each commodity, obtain copies of the Material Safety Data Sheet for hazardous materials, and distribute copies to interested persons

(n) Fulfill additional responsibilities pertaining to the Lewis Occupational Medicine Program described in LMI 1800.1

(o) Report to the Environmental Pollution Control Board at its regularly scheduled meetings

The Chief of the Office of Environmental Programs serves as the executive secretary to the Environmental Pollution Control Board and as the chairman of the Radiation Safety Committee.

Authority.—The Chief of the Office of Environmental Programs is authorized to shut down any operation on which there is a question of health hazard or on which there is a source of contamination that exceeds established air and water pollution control limits, pending an appropriate review. Exercise of this authority requires immediate notification to the chairman of the Environmental Pollution Control Board, the chairman of the Area Safety Committee involved, and the chairman of the Executive Safety Board.

1.3.9 Radiation Safety Committee

The Radiation Safety Committee provides advice, technical expertise, and guidance to minimize and/or eliminate health hazards associated with using, transporting, storing, and handling radioactive materials and sources of ionizing radiation. The Committee was established under the broad nuclear byproduct material license for the Cleveland Center to review the associated radiation program and to verify compliance with Nuclear Regulatory Commission regulations.

Responsibilities.—The Radiation Safety Committee responsibilities are to

(a) Review quarterly, or at more frequent intervals as directed by the Environmental Pollution Control Board, the precautions taken by operating officials with respect to regulating the acquisition of radioactive sources, materials, and equipment; and controlling the distribution, use, accountability, and disposal of radioactive materials and equipment

(b) Evaluate these precautions and their effectiveness, and report to the Environmental Pollution Control Board, recommending changes or improvements considered appropriate

(c) Recommend, subject to review and approval by the Environmental Pollution Control Board, minimum acceptable environmental quality standards for operations involving radioactivity

(d) Advise Area Safety Committees about ionizing radiation safety aspects of specific proposals to install, remove, or alter radioactive sources, materials, equipment, or operations

(e) Review each Safety Permit request referred by the Office of Environmental Programs

(f) Keep abreast of developments in and requirements for radiation safety

(g) Request special experiments and investigations when such activities are consistent with Lewis environmental quality objectives and policies

(h) Report to the Environmental Pollution Control Board at its regularly scheduled meetings

Authority.—The chairman of the Radiation Safety Committee is authorized to shut down any operation on which there is a question of radiation safety, until an appropriate review can be made. Exercise of this authority requires immediate notification to the chairman of the Environmental Pollution Control Board, the chairman of the Area Safety Committee involved, and the chairman of the Executive Safety Board.

> NOTE: Because of Nuclear Regulatory Commission requirements, the Radiation Safety Committee will not be overruled on decisions that reject experiments, facility modifications, or operating procedures on the basis of NRC safety requirements.

1.4 LEWIS OCCUPATIONAL MEDICINE PROGRAM

1.4.1 Scope

The Lewis Occupational Medicine Program, administered by the Office of Health Services, is a comprehensive health and safety management program that includes all aspects of health protection for Lewis employees. In order to provide continuity within these health and safety functions, the Lewis Medical Director is a consultant/advisor to the Executive Safety Board and the Environmental Pollution Control Board. The Lewis Occupational Medicine Program practices such preventive medicine techniques as appropriate physical examinations and appraisal of health hazards in the work environment, along with emergency care, and diagnosis and treatment of occupational diseases and injuries.

1.4.2 Authority

The authority for the Lewis Occupational Medicine Program comes from Public Law 89–554, "Government Organization and Employees," Public Law 90–83, "Federal Employees—Pay and Allowances, Etc.," and Public Law 91–596, "Occupational Safety and Health Act, 1970"; Executive Order 12196, "Occupational Safety and Health Programs for Federal Employees"; NHB 2710.1, "NASA Safety and Health Handbook, Occupational Safety and Health Programs"; and NMI 3792.1, "NASA Employee Assistance Program."

1.4.3 Applicability

These instructions apply to all Lewis organizational elements.

1.4.4 Policy

The Lewis Occupational Medicine Program is to be used to maintain, conserve, and improve the health of Lewis employees and to evaluate any physical, chemical, or bacteriological hazards that may be present in the employee's work environment.

Nothing in this section is to be construed as running counter to or establishing standards less comprehensive than those set forth in local, state, and Federal health regulations.

1.4.5 Responsibilities

Lewis Executive Safety Board and Environmental Pollution Control Board.—These Boards are responsible for monitoring the Lewis Occupational Medicine Program, which is coordinated and implemented by them and the following Lewis health and safety groups: the Office of Health Services; the Office of Environmental Programs; the Safety Assurance Office; the Radiation Safety Committee; and the cognizant Area Safety Committee.

Lewis Medical Director.—Through the Director of the Office of Health Services, the Medical Director

(a) Provides professional services for examining, diagnosing, and treating employee illness or injury and maintains records needed in the operation of the program

(b) Furnishes medical information to and assists the Lewis Human Resources Management Division, as required, in resolving questions about the placement and utilization of employees

(c) Consults with appropriate supervisors regarding employees who, in the judgment of a physician, may be allowed to work only if limitations on their physical activity are observed. (This applies also to new employees with physical handicaps and to employees returning to work after an illness or injury. The judgment of the employee's physician is given full consideration in such situations.)

(d) Keeps the Center Director informed, through the Chief of the Safety Assurance Office, of all cases of significant accidental injury to personnel, especially about the diagnosis, nature, and extent of injuries. This is done by direct and timely oral communication and includes subsequent followup medical reports. The severity of injuries (first aid, reportable, or lost time) is classified in accordance with Occupational Safety and Health Administration (OSHA) recordkeeping requirements.

(e) Ensures that kitchens and cafeterias are periodically inspected for conformance with local, state, and Federal health regulations

(f) Approves, prior to installation or introduction into the work area, such items as footpaths, first aid kits, salt tablets, air fresheners, and so forth

(g) Establishes procedures in conjunction with local medical facilities for emergency referral and treatment of injuries and illnesses

(h) Serves as Medical Review Official for the Lewis Drug-Free Workplace Program

(i) Serves as consultant to the Environmental Pollution Control Board

(j) Administers the Health Screening Program

(k) Administers the Physical Fitness Program

Chief of the Office of Environmental Programs.—The OEP Chief

(a) Coordinates with the Lewis Medical Director to provide professional services, and maintains the records necessary for operating the environmental health programs

(b) Provides advice on and criteria for environmental systems, shielding and absorption materials, sanitation provisions, illumination standards, noise, dust, ionizing and nonionizing radiation, vibration, temperature-humidity standards, air- and water-pollution controls, and exposure to toxic substances and biological agents

(c) Maintains a work area surveillance program that includes collecting and analyzing samples associated with potentially toxic hazards; performs periodic and special surveys of the physical environment for noise, dust, vibration, radiation, and such

(d) Develops or obtains environmental health and safety facilities and monitoring equipment commensurate with program needs

(e) Provides technical support as required by the Office of Health Services

(f) Recommends medical monitoring of certain Lewis personnel after reviewing Safety Permit Requests, Purchase Requests, and in-field monitoring and inspection activities. (Medical monitoring may include periodic physical examinations and/or laboratory analyses as appropriate to the potential hazard exposure of each employee.)

Chief of the Safety Assurance Office.—The Chief of the Safety Assurance Office

(a) Coordinates with the Lewis Medical Director to provide professional services and maintains records necessary for the operation of the safety programs

(b) Monitors illness and injury records in accordance with OSHA regulations

(c) Provides quarterly and annual reports to the Department of Labor

First-line supervisor.— It is the responsibility of the first-line supervisor to discuss with employees under his or her jurisdiction the potential exposures and health hazards in their work assignments and to make arrangements to monitor those who are exposed to potential environmental hazards. The supervisor also semiannually reviews the changes in work assignments and facilities that influence the health monitoring program. The names of employees with potential hazard exposure are forwarded to the cognizant division office along with the identity of the material or condition of concern. The division chief collects and forwards these names to the Office of Environmental Programs for forwarding to the Medical Director

Employees.—It the responsibility of all employees to maintain high standards of personal hygiene, health, and physical fitness and to notify their first-line supervisor of potential exposures to environmental health hazards in their work assignments.

1.4.6 Program Elements

Procedures for service-connected medical conditions and emergencies.—There are procedures in place for the following conditions:

Illness or injury: When any illness, service-connected injury, or health emergency occurs during work hours, the employee notifies his or her supervisor, if possible, and immediately reports to Medicine Services. If a service-connected illness becomes apparent during off-duty hours, the employee notifies his or her supervisor and Medical Services within 24 hours unless the incident occurs during a weekend or similar off-duty period, in which case notification is made at the start of the next work day. If the employee is treated by his or her personal physician for a work-related condition during off-duty hours, this fact must be reported. First-line supervisors are to inform all personnel under their jurisdiction of these requirements.

Accidental spill or exposure: If an accidental spill of hazardous substance or exposure to a hazardous material or condition occurs, the employee concerned immediately notifies Medical Services of the incident and then notifies his or her supervisor of the incident, even if no injury is apparent.

First aid: Selected personnel are trained and properly equipped to render first-aid treatment on all shifts in critical areas of operation at the Center.

Health examinations.—Health examinations are offered as follows:

(a) Special health examinations are conducted for some replacement employees, and periodic reexaminations are required for certain jobs. Such periodic examinations are required for special vehicle operators, crane operators, pilots, and employees in critical occupations where job performance could affect the health or safety of other Lewis employees.

(b) A medical monitoring program has been established for the protection of the health and safety of employees exposed to a potentially hazardous environment in a regular work assignment. First-line supervisors must notify Medical Services whenever there is a change in the potential exposure of any of their employees to hazardous substances or conditions.

(c) Each employee may take advantage of a complete physical examination once every 3 years and partial examinations in the intervening years.

Emergency services.—Ill or seriously injured personnel at the Center are transported to Medical Services by emergency vehicle unless otherwise instructed by that office. Emergency transportation at the Plum Brook Station is to the appropriate local medical facilities or hospital.

Emergency vehicle service: Emergency vehicle service may be obtained by dialing 911 at the Cleveland Center or Plum Brook Station and stating the location of the patient and the nature of the injury or illness, if known. The individual making the call should ensure that someone is at an appropriate place to direct emergency vehicle attendants to the patient. Details of the Lewis Emergency Call System are given in the Lewis Safety Manual, Chapter 21, Mishap Reporting and Accident Investigation.

Emergency treatment: Medical Services provides emergency treatment to employees to the extent feasible within the capability of available staff and facilities. If the treatment required is outside the scope of available staff or facilities, the employee is provided transportation to suitable external medical facilities. Upon return from treatment at such external medical facilities, the employee is to report to Medical Services.

Contractor emergency care: Contractor employees may receive medical care from Medical Services for such emergency services as control of bleeding, application of dressings or splints, treatment and evaluation of potentially life-threatening injuries or illness, or alleviation of pain and suffering prior to being transported to a medical facility off the Center. The Lewis ambulance service responds to contractor injuries and illnesses when necessary, and it may transport contractor employees to the hospital if the Lewis Medical Officer, a Lewis nurse, or the ambulance squad leader judges it appropriate.

Therapeutic service: Therapeutic service is a normal dispensary function available from Medical Services for the treatment of nonemergency occupational and nonoccupational injuries and illnesses. Many of these services, including followup on emergency treatment, are rendered by nurses under the supervision of a physician.

The scope of the program does not permit extensive treatment of nonoccupational injury or illness; this is the province of the employee's private physician. However, in the interest of keeping the employee on the job, reducing lost time, or relieving suffering, employees may be afforded care for minor medical-office-type illnesses or injuries.

At the written request of an employee's private physician and under his or her prescription and with the concurrence of the Lewis Medical Director, Medical Services administers medicines, changes dressings, and provides available therapy in the interest of keeping the employee on the job and saving the time he or she might spend in seeking treatment at his or her personal physician's office.

Medical release.—Following any illness or injury that results in an absence from work of 10 or more consecutive work days, the employee must obtain a medical release from his or her physician or hospital, as applicable, and report to Medical Services prior to returning to his or her duty station. This requirement is established to safeguard employees and to determine their fitness to return to duty. This requirement applies to Exchange employees as well as to other NASA employees. If there is any question about the advisability of returning to work, the lack of a physician's written medical release precludes the employee from returning to work until such permission is obtained.

Preventive services.—Annually, Lewis civil service employees are offered an extensive physical examination. Employees are contacted automatically around the time of their birthdays to set up appointments; no independent action on the part of the employee is required. Employees are also encouraged to take advantage of other preventive services offered, such as health education programs on topics important to employee health, and the immunization service for overseas travelers.

Review and modification of facilities.—Periodic reviews are conducted to investigate the existence of potential environmental health hazards in the work areas of the Center. When, in the professional opinion(s) of the Medical Director, the Environmental Health Officer, the Radiation Safety Committee, the cognizant Area Safety Committee, or the Safety Officer, environmental conditions are deemed to constitute a hazard to the health of an employee, studies are to be conducted to determine a means of modifying or eliminating such hazardous conditions. The Safety Officer is responsible for implementing the recommendations of such studies.

Records.—The Medical Director establishes and maintains a medical file for each employee who is examined by Medical Services, including those whose work requires exposure to potential health hazards. **This file is maintained in accordance with the Privacy Act and is considered to be privileged information; information therefrom is conveyed to persons outside Medical Services only as follows:**

(a) To an employee's private physician or to the employee's representative upon the request and written permission of the employee

(b) To the chairman of the Executive Safety Board, the chairman of the Environmental Pollution Control Board, cognizant members of the Human Resources Management Division staff, and appropriate management officials, in the form of findings of fact, conclusions, and recommendations, when such information is necessary to evaluate the employee's ability to do his or her job, the employee's eligibility for disability retirement, or the employee's conformance with prescribed health standards

Radiation exposure records of individual employees are maintained by the Office of Environmental Programs.

1.5 SAFETY PERMIT SYSTEM

1.5.1 Scope

The Safety Permit constitutes a license to operate a facility or piece of equipment within the constraints indicated therein. A Safety Permit is required for all operations of systems and some support systems and experiments used in a test rig. A Safety Permit is also required for certain construction activities associated with work on or around high voltage electrical power systems. A Safety Permit is not generally required for routine maintenance and operational activities. The Area Safety Committee chairman and the Safety Assurance Office shall determine if a Safety Permit Request should be initiated.

1.5.2 Applicability

These instructions on the Safety Permit System apply to all Cleveland and Plum Brook Station facilities and technical operations and to organizational elements and personnel involved in offsite operations.

1.5.3 Authority

The authority for the Safety Permit System comes from the Lewis Safety Manual, Section 1.2, Lewis Safety Organization, and Section 1.3, Lewis Environmental Quality Organization.

1.5.4 Policy

It is the responsibility of cognizant personnel assigned to a system or operation to ensure that its design and operations are safe. All systems should be designed to fulfill fail-safe requirements and to avoid an unsafe situation in an interfacing system. A Safety Permit Request must be submitted to the cognizant Area Safety Committee and to the Office of Environmental Programs for all proposed Lewis test operations. If the Committee, after reviewing the request, decides there is no attendant potential hazard, it notifies the requester that no Safety Permit is required. If a hazard is judged to exist, then the Committee conducts an appropriate safety review before issuing a Safety Permit.

1.5.5 Forms and Rules

<u>Safety Permit Request (NASA Form C-923)</u>.—Form C-923 (attachment 1 in the appendix) constitutes **formal** application for permission to operate a facility, rig, system, experiment, or such. The formal request must be submitted to the cognizant Area Safety Committee, after review by the Office of Environmental Programs, no less than 30 days prior to the contemplated initiation of operation. As described later, notification of and discussions with the cognizant Area Safety Committee is required at the time the conceptual design is completed so that the specific requirements for analyses, drawings, and the like may be established, thus precluding unnecessary repetition of the safety review.

Safety Permit (NASA Form C-919).—Form C-919 (attachment 2 in the appendix) indicates that a facility, rig, system, experiment, or operation has been reviewed by an Area Safety Committee; it constitutes a license to operate the facility within the constraints indicated thereon. A Safety Permit is valid for a 1-, 2-, or 3-year period from the date of issue, as determined by the cognizant Safety Committee.

Expired Safety Permits.—Operation of any facility, rig, system, or experiment is forbidden if the governing Safety Permit has expired. All personnel are under instructions not to operate or perform work unless the activity is covered by a valid permit.

Safety Permit Renewal Request (NASA Form C-590).—A Safety Permit Renewal Request (attachment 3 in the appendix) must be submitted no later than 30 days prior to the expiration date of the Safety Permit. The routing of the Renewal Request is the same as for an initial Safety Permit Request.

Changes to reign or operational limits.—A Safety Permit is invalidated by any change in the apparatus, operating conditions, or mode of operation from those described in the Permit and supporting documentation, unless the change has been approved by the cognizant Area Safety Committee.

Operational Safety Plan.—The Operational Safety Plan consists of a compilation of hazard descriptions, checklists, redlines and limits, and operating and emergency procedures (accompanied by appropriate drawings and specifications) pertinent to the activity governed by the Safety Permit. Granting a Safety Permit shows concurrence by the Area Safety Committee in the Safety Plan. The specific contents and depth of detail required are functions of the nature of the particular activity and are determined by the cognizant Area Safety Committee during the discussions with the Safety Permit requester.

Safety review.—An independent review of the proposed activity is conducted by the cognizant Area Safety Committee to determine that appropriate design and operations safety standards have been employed. Notwithstanding such review, it is the responsibility of the requesting group(s) to ensure that the system design and operation are safe.

Qualified Facilities Operators List (NASA Form C-580).— Form C-580 (attachment 4 in the appendix) lists qualified facilities operators and describes the experience and training requirements for each operator. This document should be used only in conjunction with a valid Safety Permit.

1.5.6 Safety Permit Hazards Identification

A color-coded sticker affixed to the Safety Permit provides immediate identification of the potential hazard level and the instructions for emergency action to be taken. The color codes used and their meanings are as follows:

Color code	Hazard level	Take action?	Emergency action
Red	Unique; high explosion potential, high toxicity, nuclear radiation, etc.	ONLY on advice of knowledgeable person (Project manager or alternate)	NOTIFY "Emergency Contact" named on Safety Permit
Yellow	Potential of fire involving liquid metals, high voltage, etc.	Yes	Use DRY chemicals ONLY; then notify "Emergency Contact" named on Safety Permit
Green	No unusual or unique hazard	Yes	Use water, dry chemicals, or CO_2; then notify "Emergency Contact" named on Safety Permit

1.5.7 Requirements and Procedures

Initial request for a Safety Permit.—The following steps are required to obtain a Safety Permit:

(a) When a decision has been made to undertake a new activity, the conceptual design has been agreed on, and the general location has been selected, the responsible person (the Safety Permit requester) contacts the chairman of the cognizant Area Safety Committee and arranges for a meeting with the Committee. At this meeting the requester describes the design, citing considerations, operating conditions, the need for a Qualified Facilities Operators List (NASA Form C-580), and so forth. The committee responds by indicating the nature and detail of documentation and analyses that should accompany the formal Safety Permit Request. Also, the number and nature of additional meetings are established. The Committee may counsel the requester to consult with advisory bodies and may furnish examples of the documentation it requires. The key element is early notification of and continuing involvement by the Area Safety Committee through incremental progress meetings.

(b) When the design is complete, and no less than 30 days prior to the planned initiation of operations, the requester prepares and submits the Safety Permit Request (NASA Form C-923) to the Office of Environmental Programs. It must be signed by the chiefs of the initiating division and branch, and all pertinent documentation (as described in Sec. 1.5.8) must be attached.

(c) The Office of Environmental Programs (OEP) reviews the Safety Permit Request, asks for additional information or revisions, if necessary, and notes any requirement for a Red Hazard Area sticker, indicating environmental health hazards. After the OEP requirements are satisfied, the Safety Permit Request is signed and the entire package is returned to the requester. The requester then forwards the package to the chairman of the cognizant Area Safety Committee.

(d) The Area Safety Committee conducts its review of the proposed operation. Reviews are normally conducted by a majority of the members of the committee.

In no case should the review be made by a single member. The Area Safety Committee may call on advisory bodies to assist it and may require a meeting with the requesting individual or group. Opinions, concurrences, or clarifications are to be documented and preserved as part of the review record. If changes are required on the Safety Permit Request, the package is returned to the requester. After making the required changes, the requester resubmits the request to the Office of Environmental Programs and proceeds as directed in Section 1.5.7. The Area Safety Committee, when satisfied, issues a Safety Permit.

(e) The Area Safety Committee chairman retains the originals of the Safety Permit, the Safety Permit Request, and all supporting documentation for the Committee files. A copy of the Safety Permit (with the colored hazard identification sticker attached) and a copy of the Safety Permit Request are sent to the requester; copies of both are also sent to the Lewis Safety Assurance Office and the Office of Environmental Programs.

(f) The requester posts the copy of the approved Safety Permit (together with an attached copy of the Safety Permit Request and the C-580) in a **conspicuous place** at the specified site, or if more practical, in the applicable control center of the site.

<u>Renewal of a Safety Permit.</u>—If there are no changes to the operation and the activity will not be completed before the Safety Permit expires, then at least 30 days prior to the Safety Permit expiration, the requester

(a) Completes a Safety Permit Request (Form C-590)

(b) Includes an updated Qualified Facilities Operator List if the original Safety Permit required one

(c) Forwards the package to the Office of Environmental Programs

(d) After OEP approval, sends the package to the chairman of the cognizant Safety Committee.

After the Area Safety Committee reviews the renewal request and approves renewal, the chairman of the Committee makes the necessary revisions to the expiration date on the original Permit and initials the change. A copy of the renewed Safety Permit (with the hazards identification sticker attached) and a copy of the Safety Permit Renewal Request are sent to the requester. Copies are also sent to the Lewis Safety Assurance Office and the Office of Environmental Programs. The originals are retained in the Safety Committee files. The requester then posts the renewed permit, the renewal request, and the updated Qualified Facilities Operators List.

<u>Modification of a Safety Permit.</u>—If there is a change in the purpose, procedures, operational limits, constraints, or design of the activity, a modification of the Safety Permit must be requested. To accomplish this the requester submits a new Safety Permit Request, employing the sequence and procedures in Section 1.5.7. The accompanying documentation should consist primarily of amendments to the documents originally submitted, together with the appropriate explanatory narrative. The Office

of Environmental Programs and the cognizant Area Safety Committee then conduct the necessary review. When the Office of Environmental Programs and the Committee approve, the chairman either issues a new Safety Permit or makes the necessary revisions to the existing Safety Permit and initials the changes. The records of the review are added to those of the original Safety Permit. The revised Safety Permit and the C-580 are sent to the Safety Assurance Office and the Office of Environmental Programs.

Completion of an activity.—Upon completion of the operation or activity covered by a Safety Permit, the responsible individual

(a) Removes, dates, and signs the copy of the Safety Permit in the space provided and returns the Safety Permit to the Area Safety Committee chairman. The chairman removes the original from the files, marks it canceled, forwards it to the Lewis Safety Assurance Office, and destroys the copy.

(b) Coordinates phase out of the operation site, disposition of equipment, and removal and proper disposal of all hazardous material in accordance with the applicable safety standards

The Lewis Safety Assurance Office removes the Permit from its files and forwards the original to the Office of Environmental Programs. The Office of Environmental Programs destroys the Permit after it has cleared its records.

1.5.8 Supporting Documentation

Accompanying each Safety Permit Request is the pertinent documentation agreed on at the first meeting with the Area Safety Committee. This documentation should be sufficient to permit the reviewers to understand and assess the hazards that are involved in the activity, the safety standards applied, the operational safeguards planned, and the like. In general, the amount or extent of necessary supporting documentation depends on the complexity of the experiment, the risk of failure, and the severity of a failure. Typically, the documentation to the Area Safety Committee should include, but is not necessarily be limited to, the following items:

Technical description.—A brief technical description of the experiment or activity should include the desired range of environmental test parameters and cite factors such as maximum stored energy and quantity-distance criteria.

Schematic diagrams or key drawings.—Drawings (dated and with approval signatures) of such equipment as test hardware; control systems; laser systems; electrical systems for the facility, cell, or test rig (indicating class of electrical equipment used); and flow systems (including parts list, line sizes, working pressures, materials, etc.) should be submitted.

Operational procedures.—Check sheets, where appropriate, along with safety monitoring data, permissives, abort limits, redline limits, emergency shutdown procedures, and so on should be included. Check sheets are to be approved by a knowledgeable supervisor or project authority prior to Area Safety Committee review.

Hazard analyses.—Early in the program development, hazardous conditions need to be identified and corrective actions determined. Hazard analyses such as Preliminary Hazards Analysis, Failure Mode and Effects Analysis, Fault Hazards Analysis, Operational Hazard Analysis, and Fault Tree Analysis are to be identified and made part of the development of the system safety plan. The severity of failures are to be identified and categorized as follows:

Hazard class	Severity	Effect of equipment failure or operational error
I	Catastrophic	Death, serious injury, or mission loss
II	Critical	Severe injury or major property damage (>$25,000)
III	Marginal	Minor injury or property damage (<$25,000)
IV	Negligible	No injury or property damage (system function can be restored in short time with repair or maintenance procedures)

Hazard probability.—The probability that a hazard will occur during the planned operational life of a system is to be described in the hazard analyses through a qualitative hazard probability ranking:

Hazard ranking	Probability of hazard
A	Likely to occur immediately
B	Likely to occur in time
C	May occur in time
D	Unlikely to occur

Where appropriate, supporting rationale for assigning a hazard probability may be documented in hazard analysis reports.

Design margins and operating limits.—To minimize the chance of failure, an analysis of **design limits and/or redline operating limits** (with analytical methods used and results of supporting calculations) must be provided. **Wherever possible, designs are to be fail-safe or fail-passive.** Safety factors or safety margins and quantity-distance criteria must be provided, as appropriate.

Plot plan of test area.—A drawing of the test area showing equipment, type and location of personnel-protective equipment, warning signs, barricades, and/or warning lights used during testing must be provided.

Certification of qualified operators.—When the circumstances of the activity warrant special training and/or certification of personnel, the names of the personnel who are assigned to operate or are responsible for the test rig, experiment, or operation are to be submitted with a description of the experience and training requirements.

Emergency plan.—An emergency reaction plan including all procedures for shutdown, sequence of notifications, and so on must be provided.

Buddy system.—The preferred level of protection to ensure the safety of personnel is prescribed in the Lewis Safety Manual, Chapter 13, Confined Space Entry.

Users Radiological Training and Experience Record (NASA Form C-197).—When the use of radioactive materials or radiation-producing equipment is involved, a C–197 for each user must be attached. A user is defined as a person qualified by training and experience to use radioactive material and ionizing radiation-producing devices in a safe manner. The user is responsible for the safekeeping of use material and equipment, as specified in the Safety Permit under his or her control.

1.5.9 Responsibilities

Requester (usually the project engineer).—The requester's responsibilities are to

(a) Notify the cognizant Area Safety Committee chairman, after the conceptual design is approved, of the forthcoming new operation, and arrange for an introductory meeting

(b) Prepare the Safety Permit Request and arrange for all required supporting documentation, allowing for appropriate lead time.

(c) Respond to all action items and requests for further information levied by the cognizant Area Safety Committee

(d) Take necessary and timely action to obtain renewal of a Safety Permit

(e) Advise the cognizant Area Safety Committee of contemplated changes to the operation or equipment and take necessary action to obtain a revised Safety Permit

(f) Take necessary action to close out a Safety Permit on completion of operations

Cognizant Area Safety Committee.—Responsibilities of the cognizant Area Safety Committee are to

(a) Conduct reviews of proposals for all research operations, for modifications or additions to facilities and equipment, and for any activities that affect safety within the assigned safety areas; approve and issue Safety Permits for those proposals that meet Lewis safety requirements, contingent on receiving sufficiently complete technical information that satisfies all questions relative to safety and on being satisfied that fail-safe requirements have been fulfilled. (Requesters may appeal rejections, through the initiating division chief, to the Executive Safety Board.)

(b) Notify the requester when it has determined that a Safety Permit is not required. The chairman notes this on the request, affixes his or her signature, and returns it to the requester through the Office of Environmental Programs.

(c) Consult, as required, with the Safety Assurance Office, the Office of Environmental Programs, and advisory panels, on safety and environmental matters that fall within their areas of specialization. All reviews and concurrences are to be a part of the safety review documentation and should be available for any required post-accident investigation.

(d) Specify, when appropriate, the need for qualified operators or any special conditions on which the approval is based.

(e) Conduct annual reviews to ensure that existing Safety Permits are current, that is, that they have not expired, or that they have been reviewed prior to their expiration date. The chairman is responsible for initialing the original Safety Permit to certify that it has received its annual review.

(f) Refer major safety issues or questions of significant risk assessment to the Executive Safety Board.

Lewis Safety Assurance Office.—Responsibilities of the Safety Assurance Office are to

(a) Administer, coordinate, and implement the Safety Permit Program at the Cleveland Center and the Plum Brook Station

(b) Participate (ex-officio) in the safety review process when necessary

(c) Provide overall surveillance of the Safety Permit system

Executive Safety Board.—Responsibilities of the Executive Safety Board are to

(a) Review and evaluate disputes concerning safety conditions, in the deliberations prior to the granting of a Safety Permit and in all major risk assessments submitted to it by a cognizant Area Safety Committee

(b) Submit to the Director a written report reflecting its evaluations and recommendations on major risk assessments

EXCEPTION: When Nuclear Regulatory Commission (NRC) requirements are involved, decisions of the Radiation Safety Committee for Cleveland cannot be overruled.

Office of Environmental Programs.—Responsibilities of the Office of Environmental Programs are to

(a) Review requests for Safety Permits, examining them for impact on the environment, for creation of radiological hazards, or for hazards to the worker because of toxic materials or hazardous conditions; consult with advisory panels or Area Safety Committees concerning matters under their cognizance

(b) Indicate concurrences, after noting any special requirements, by signing the Safety Permit Request (or Safety Permit Renewal Request) at the appropriate location thereon

(c) Return the Safety Permit Request, with all drawings and information, to the requester so that it can be forwarded to the appropriate Safety Committee chairman

1.5.10 Offsite Operations

Lewis employees at another NASA center or Government agency.—If an operation is conducted at a site or in facilities of another NASA center or Government agency, or in their aircraft or vessels, the safety review and approval procedures of the Center or agency govern and are to be complied with; a Lewis Safety Permit is not required. The Lewis employee in charge must take positive action on his or her own initiative to ascertain the host organization's requirements for safety approval and must see that they are fulfilled. No Lewis operation may be conducted without such safety approval. In addition, the Lewis employee in charge must inform the Lewis Safety Assurance Office, by letter, of the nature and character of the offsite operation. The Chief of the SAO is not responsible for reviewing and approving the operation (this is the responsibility of the host organization). However, if the Lewis employee has a significant concern based on his or her experience and expertise, the employee may request that the chairman of the Lewis Executive Safety Board have the matter appropriately investigated.

Lewis employees at unhosted site.—If Lewis personnel conduct an offsite operation where there is no host organization, and if the whole organization has no properly approved safety procedures in effect or the whole organization places all or part of the safety approval under Lewis' responsibility, the operation is subject to the same rules and regulations set forth in the Lewis Safety Manual for onsite operations. All such offsite operations require preparation of a Safety Permit Request in accordance with this Manual. The offsite request is submitted to the Lewis Safety Assurance Office for appropriate safety review and determination.

Government-retained offsite personnel.—Non-Government members of an offsite research team, when retained as Government experts or consultants (i.e., special Government employees), are also required to observe the pertinent regulations of the Lewis Safety Manual. The Lewis employee in charge ensures that a copy of such regulations and related instructions is made available. Safety regulations of other Government agencies involved are recognized as a part of the total safety requirement for the program and are to be adhered to by all Lewis personnel concerned.

1.5.11 Certification of Qualified Facilities Operators

Requester.—The Safety Permit requester completes NASA Form C-580, Qualified Facilities Operators List, and submits it to the cognizant Area Safety Committee chairman together with the NASA Form C-923, Safety Permit Request. The requester also includes supporting documentation, as required, of the applicable training programs provided to personnel listed on the C-580.

The operators training program requested by the C-580 should include, but not be limited to, developing safety awareness and making operators fully knowledgeable of and alert to potential hazards that could exist within their work environments.

Cognizant Area Safety Committee.—The Area Safety Committee reviews and approves the NASA Form C-580, Qualified Facilities Operators List. It also ensures, by requesting supporting documentation from the requester, that training programs have been conducted as required. The Safety Permit may not be issued until the Qualified Facilities Operators List is approved.

1.6 APPENDIX—SAFETY PERMIT FORMS AND QUALIFIED FACILITIES OPERATORS LIST

ATTACHMENT 1

SAFETY PERMIT REQUEST

SAFETY COMMITTEE USE ONLY	DATE	PERMIT NO.
		PREVIOUS
		NEW

TO: ☐ AREA SAFETY COMMITTEE NO. ______

EMERGENCY CONTACT	HOME PHONE
(Knowledgeable person)	
(Alternate)	

FROM:

PROJECT ENGINEER NAME *(Responsible Engineer)*	ORG. CODE	PABX	MAIL STOP

1. ACTIVITY *(Describe research operation, facility, equipment, etc., requiring safety approval)*

2. LOCATION *(Room, building, cell, etc.)*	3. DRAWING NOS.	4. WORK UNIT NO. *(Task)*

5. TESTS *(Nature of objectives, etc.)*

6. EXPECTED DURATION DATES

START ______

COMPLETE ______

7. TEST RUNS

LENGTH: ______

TIME: ☐ WORKDAY ☐ NIGHT ☐ WEEKEND

8. TEST CONDITIONS *(List the most hazardous conditions; use of fluids, power, radiation, etc.)*

MATERIAL, FLUID, ETC.	VOLTAGE, PRESSURE, ETC.	FREQUENCY, TEMPERATURE, ETC.	QUANTITY		REMARKS
			AT SITE	IN RIG	

9. MATERIALS DESCRIPTION *("X" Blocks for materials to be used)*

☐ TOXIC
☐ PYROPHORIC
☐ CORROSIVE
☐ RADIOACTIVE
☐ MEDICAL MONITORING REQUIRED FOR PERSONNEL
☐ EXPLOSIVE
☐ OTHER *(Specify)* ______

10. DESCRIPTION OF RADIATION AND/OR RADIOACTIVE MATERIAL *(Complete and attach Users Radiological Training & Experience Record (NASA-C-197) for each user)*

PHYSICAL FORM:
☐ SEALED SOURCE
☐ UNSEALED SOURCE
☐ GAS
☐ LIQUID
☐ SOLID

TYPE OF RADIATION:
☐ ALPHA ☐ GAMMA
☐ BETA ☐ NEUTRON
☐ OTHER *(Describe if such as X-ray producing equipment)* ______

ELEMENT OR COMPOUND ______
ELEMENT OR COMPOUND WEIGHT ______
RADIOACTIVE ISOTOPE ______
WEIGHT % RAD. ISO. IN ELEMENT/COMP. ______
ACTIVITY CURIES ______

11. RADIATION DETECTION INSTRUMENTS

INSTRUCTIONS: If required *(See LMI 1703.1)*, attach pertinent drawings, hazards analysis and/or Users Radiological Training and Experience Record *(NASA-C-197)*

At Cleveland, send copy of this request with backup material as required to Environmental Health and Chemical Analysis Branch *(EHCAB)*. After completion of investigation and/or sign-off by EHCAB, request shall be submitted to cognizant Area Committee Chairman through the Requester.

At Plum Brook Station, send copy with backup material as required to the Plum Brook Management Office, which shall forward the request to the Environmental Health and Chemical Analysis Branch.

NASA-C-923 (Rev. 4-88) **MUST BE POSTED WITH SAFETY PERMIT**

ATTACHMENT 1

12. IS THERE A PRECEDENT FOR THIS WORK? *(If "Yes", give details)* ☐ YES ☐ NO	13. NASA-C-197 *(attached)* ☐ YES ☐ NO *(Names)*

14. DISCHARGE PRODUCTS *(Radioactive, corrosive, combustible, toxic and air/water pollution materials)*

PRODUCTS: Temperature Radioactive, Noise, Toxic, Hazards *(Quantity or Degree)*	MEANS OF COPING WITH DISCHARGE PRODUCTS *(Abatement Device or Treatment Process)*	EFFLUENT DISCHARGED TO	SAMPLING FREQUENCY	TYPE OF DETECTION	MONITORING GROUP

15. SAFETY PRECAUTIONS *(Indicate what provisions have been made for the following typical items)*

SITUATION	SAFETY PRECAUTION
A. Ventilation	
B. Detection of hazardous condition *(Radiation, toxicity, etc.)*	
C. Ignition sources	
D. Safe location of personnel during tests	
E. Avoidance of unsafe contamination of fuel or oxidant	
F. "Fail-Safe" means in case of power, pressure, combustion or personnel failure	
G. Protective means in case of over-temperature, over-pressure, or over-speed	
H. Accident Procedure *(Fire, explosion, spill)*	
I. Collapse of vessel from evacuation	
J. Personnel protection *(Protective clothing, breathing, apparatus, medical check, etc.)*	
K. Grounding	
L. Guarding of live parts	
M. Shielding *(Radioactive material, radiation producing equipment, and high frequency radiation)*	
N. Hazard - warning signs	
O. Level of buddy system	

16. SPECIAL ITEMS *(List pertinent items peculiar to conditions of proposed test)*

PROJECT ENGINEER *(Signature)*	DATE	REQUESTING DIVISION CHIEF *(Signature)*	DATE
SUPERVISOR *(Signature)*	DATE	ENVIRONMENTAL HEALTH & CHEMICAL ANALYSIS BRANCH	DATE

NASA-C-923 (Rev. 4-88) Reverse **MUST BE POSTED WITH SAFETY PERMIT**

NOTE: COPY OF SAFETY PERMIT REQUEST MUST BE POSTED WITH THIS PERMIT.

NASA

National Aeronautics and Space Administration

Lewis Research Center
Cleveland, Ohio

SAFETY PERMIT

SAFETY AREA	
PERMIT NO.	
DATE ISSUED	EXPIRATION DATE
WORK UNIT NUMBER (TASK)	
REPLACES PERMIT NO.	

LOCATION *(Room, building, cell, etc.)*

DRAWING NOS.

ACTIVITY *(Describe research operation, facility equipment, etc., requiring safety approval.)*

(Affix color coded sticker here.)

EMERGENCY CONTACT	HOME PHONE
(Knowledgeable person)	
(Alternate)	

ACTIVITY APPROVED FOR SAFETY SUBJECT TO THE FOLLOWING CONDITIONS:

SAFETY APPROVAL REQUESTED BY
(Project Engineer's name)

AREA SAFETY COMMITTEE		ACTIVITY COMPLETED	
REVIEWED BY	APPROVED *(Chairman)*	DATE	SIGNATURE

INSTRUCTIONS

Area Safety Committee Chairman

After approval of the Safety Permit Request *(NASA-C-923)*, complete this permit in accordance with procedures prescribed in LMI 1703.1 and send one copy to each of the following for:

CLEVELAND

Project engineer *(Resp. Eng.)*

Environmental Health & Chemical Analysis Br.

Safety Operations Branch

PLUM BROOK

Safety Operations Branch

Project engineer *(Resp. Eng.)*

Plum Brook Management Office

Project Engineer *(Responsible Engineer)*

1. Post a copy of this Permit, together with a copy of the Safety Permit Request and a copy of the Safety Permit Renewal Request *(when applicable)* at the location described.
2. Submit a new Safety Permit Request *(NASA-C-923)* if:
   a. the activity will not be completed by the expiration date;
   b. any change is made in conditions as described in this permit.
3. Submit a Safety Permit Renewal Request *(NASA-C-590)* at least 30 days prior to the expiration date if:
   a. the activity will not be completed by the expiration date
   b. no change is made to the operation as described in this Permit
4. When the activity is completed, remove this permit, indicate the completion date, and send it to the cognizant Area Safety Committee chairman.

NASA-C-919 (Rev. 4-86)

NASA-Lewis

SAFETY PERMIT RENEWAL REQUEST	SAFETY PERMIT NO.
	EXPIRATION DATE
	SAFETY AREA
TITLE	LOCATION *(Room, Bldg., Cell, etc.)*

Review has been made of the activities covered by the Safety Permit identified above. This review revealed no changes in the purpose, procedures, operational limits, constraints, or design of the facility or operations. No new hazards have been identified.

Logistical changes such as qualified operators, phone numbers, emergency contacts, etc., are noted below.

LOGISTICAL CHANGES

RENEWAL REQUESTED BY *(Name)*		ORG.	MAIL STOP	PABX
REQUESTER *(Signature)*	DATE	REQUESTING DIVISION CHIEF *(Signature)*		DATE
SUPERVISOR*(Signature)*	DATE			

Attach copy of current Safety Permit to this request and send to Environmental Health and Chemical Analysis Branch *(Mail Stop 21-15)* for approval. When approval is received from Environmental Health and Chemical Analysis Branch, forward to Cognizant Area Safety Chairman.

APPROVALS

ENVIRONMENTAL HEALTH and CHEMICAL ANALYSIS BRANCH *(Signature)*	DATE
AREA SAFETY COMMITTEE CHAIRMAN *(Signature)*	DATE

NASA-C-590 (Rev. 11-86)

MUST BE POSTED WITH SAFETY PERMIT

QUALIFIED FACILITIES OPERATORS LIST				DATE
TYPE OF FACILITY, EQUIPMENT/RESEARCH APPARATUS OR DESCRIPTION OF OPERATION				
BUILDING *(Name)*	CELL NUMBER		ROOM NUMBER	
ORGANIZATION CODE		SAFETY PERMIT NUMBER		
EXPERIENCE AND TRAINING REQUIREMENTS				

QUALIFIED FACILITIES OPERATORS			
NAME	ORG. CODE	NAME	ORG. CODE

APPROVALS	DATE
REQUESTER OF SAFETY APPROVAL	
BRANCH CHIEF OF QUALIFIED FACILITY OPERATORS	
SAFETY COMMITTEE CHAIRMAN	

INSTRUCTIONS

1. Attach to the Safety Permit at the specific facility, equipment, and/or research apparatus.
2. Safety Committee Chairman will assure that the Qualified Facilities Operators List is current and training programs have been conducted during reviews/inspections of test rigs, facility systems and equipment.
3. Line management will implement training programs to certify qualified operators and review the form concurrently with Safety Permit renewal.
4. Training shall be classroom work and/or on-the-job training. Written procedures and/or manuals shall be referenced.

NASA-C-580 (Rev. 8-86)

1.7 BIBLIOGRAPHY

Executive Order 11514. U.S. Code Congressional and Administrative News. 1970. Protection and Enhancement of Environmental Quality.

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LHB 7910.2. NASA Lewis Research Center Handbook. 1989. Research Flight Operations and Airworthiness Procedures.

LMI 1704.1, as revised. NASA Lewis Research Center Management Instructions. Protection of Employees Through the Buddy System.

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LMI 1800.1, as revised. NASA Lewis Research Center Management Instructions. Lewis Occupational Medicine Program.

NHB 1700.1. NASA Handbook. 1983. NASA Basic Safety Manual. (NASA TM–85234.)

NHB 1700.6. NASA Office of Safety and Environmental Health. 1976. Guide for Inservice Inspection of Ground-Based Pressure Vessels and Systems.

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NHB 8800.11. NASA Handbook. 1988. Implementing the Provisions of the National Environmental Policy Act.

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Title 29, Code of Federal Regulations, Pt. 1910. Occupational Safety and Health Standards.

Chapter 2. TRAINING REQUIREMENTS

Chapter 2. TRAINING REQUIREMENTS

2.1 SCOPE

This chapter establishes policy and procedures and assigns responsibilities for safety training of Lewis employees. It also describes the minimum requirements for the various certification levels for personnel involved in potentially hazardous operations. This chapter is not a direct instruction to contractors, but provides guidance for Lewis officials responsible for ensuring NASA contractor compliance with personnel safety training and certification.

2.2 DEFINITIONS

(a) Certified personnel (CP). Those who meet the requirements set forth by the authority responsible for certification. CP's are **not** associated with Safety Permits, as for the operation of a test rig or facility.

(b) Hazardous material. A substance or material in a quantity and form which may pose an unreasonable risk to health and safety or property when transported in commerce (49 CFR 171.8). The Secretary of Transportation has developed a list of hazardous materials, which may be found in 49 CFR 172.101.

(c) Potentially hazardous operations. Operations in which hazardous materials are used or handled or in which other materials, phenomena, or elements are used at such abnormal environmental or physical parameters that personnel injury or illness or property damage could result if special precautions are not followed (e.g., high-pressure gas operations in excess of 150 psig; low-pressure, high-volume gas operations; voltages above 110 volts; storage or handling of propellants or explosives; use of heavy lift material-handling equipment; high- or low-temperature environments; environments with less than 19.5 vol % or more than 25 vol % oxygen at normal atmospheric pressure; forced variations in gravity; excessive radiation; or excessive noise as defined by national consensus standards or Lewis-established standards, whichever is stricter).

2.3 APPLICABILITY

The procedures, responsibilities, and requirements as set forth in this chapter apply to Lewis employees, to all NASA contractors in accordance with the terms of the contract, and to other Government agency employees who support operations at Cleveland, Plum Brook, and other facilities under Lewis Research Center cognizance.

This chapter does not apply to personnel who operate a test rig or facility requiring a Safety Permit. The certification of qualified facilities operators is specified in Chapter 1, Section 1.5, Safety Permit System.

This chapter does not apply to personnel engaged in skill operations, such as soldering, brazing, crimping, and potting, already certified by quality assurance organizations or to personnel performing inspections with dye penetrant, magnetic particles, ultrasound, radiography, magnaflux, and such.

Nothing in this chapter shall be used as a justification for allowing hazardous duty payments, environmental differential pay, or premium pay; nor will the fact that a job qualifies for hazardous duty pay imply that it is covered by this chapter. It has always been NASA policy to make all operations, even potentially hazardous testing, as safe as possible.

2.4 AUTHORITY

The authority for these policies and procedures derives from Executive Order No. 12196; 29 CFR 1960, "Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters," Subpart H; and NHB 1700.1, the "NASA Basic Safety Manual," Chapter 6.

2.5 POLICY

It is the policy of Lewis Research Center to administer its operations so as to ensure that personnel at Lewis are trained to perform their work in accordance with applicable safety and health standards and to employ careful and safe methods of operation, thus ensuring high standards of reliability and protecting the Center's mission. People who perform or control hazardous operations or who use or transport hazardous material must possess the necessary knowledge, skill, judgment, physical ability (if specified in the job classification), and certification to do the job safely and in a healthful manner.

2.6 RESPONSIBILITIES

2.6.1 Safety Training

Although line management bears the prime responsibility for the safety training of employees and the safe operation of facilities and equipment, employees also have a direct responsibility in the proper functioning of the Center safety program; they should follow safe work practices, properly use protective clothing and equipment, report mishaps in a timely manner, and implement any indicated corrective actions.

In addition, the Office of Mission Safety and Assurance (OMS&A) and the Safety Assurance Office (SAO) (with assistance as needed from the Technical and Administrative Training Branch (T&ATB), the Office of Environmental Programs (OEP), and line management) are responsible for coordinating occupational safety and health training needs and overseeing training efforts. To do this, they must

(a) Identify safety- and health-related training needs

(b) Determine budget requirements for training

(c) Develop safety- and health-related training courses

(d) Ensure that training records reflect employee safety training

2.6.2 Certification Program

The responsibility for overall policy development of the certification program rests with the Office of Mission Safety and Assurance. Other organizations' responsibilities are as follows:

Line management.—Each line organization is responsible for managing the certification program for its employees and contractors in accordance with the policies in this chapter. As the certifying authority, line management is responsible for

(a) Establishing certification requirements for certified personnel (CP) in accordance with minimum standards set forth in this chapter

(b) Tracking and documenting certification requirements, and maintaining CP rosters (NASA Form C-9874) or issuing an Operators Card

(c) Notifying, retraining, and retesting those personnel who fail to meet minimum certification requirements

(d) Ensuring that recertification training is conducted prior to the expiration date of a CP's certification

Medical services.—The Office of Health Services is responsible for

(a) Determining the need for physical examinations that will establish fitness for duty or that assist in establishing a baseline or occupational exposure level

(b) Overseeing or conducting the required medical examinations in support of the certification effort and ensuring compliance with OSHA and other federal, state, and local agency medical monitoring and recordkeeping requirements

(c) Conducting initial, routine, and termination examinations for those personnel in categories of hazardous operations that require a medical examination

Safety Assurance Office.—The SAO is responsible for

(a) Reviewing certification requirements set forth by the certifying authority, thereby ensuring that the minimum standards are met

(b) Auditing the certifying authority periodically to ensure that documentation of personnel training and certification is proper and consistent with the requirements set forth in this chapter

Technical and Administrative Training Branch.—The T&ATB is responsible for

(a) Assisting line management and the Safety Assurance Office in facilitating safety certification training courses for Center personnel

(b) Maintaining and updating training records as personnel complete training courses, and annotating those records as personnel successfully pass the certification requirements

2.7 SAFETY TRAINING

2.7.1 Target Groups

Appropriate instruction and job-related safety information are required for all employees, with additional emphasis for

(a) Managers and supervisors

(b) Collateral duty safety personnel and Area Safety Committee members

(c) Employee representatives

2.7.2 Training Areas

The training program will be structured to ensure, at a minimum, that the following information is provided to all Lewis employees and to others as applicable:

(a) Essential features of Public Law 91–596, the "Occupational Safety and Health Act (1970)"

(b) Essential features of Executive Order 12196, "Occupational Safety and Health Programs for Federal Employees"

(c) Requirements of 29 CFR 1960.59, "Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters"

(d) NASA's and Lewis' Occupational Safety and Health Programs and pertinent publications and directives

(e) Individual employee rights and responsibilities

(f) Specific job-related safety and health information such as hazards of the job; safe work practices; hazards of the work environment; use and care of personal protective equipment; first aid procedures; and reporting of injuries, illnesses, and hazardous conditions

2.7.3 Target Group Training Needs

Managers and supervisors.—Occupational safety training for managers and supervisory employees will be provided so that they can identify and report safety hazards in their work environments and identify and strive to eliminate unhealthful and unsafe work methods of their employees. This training will cover Section 19 of Public Law 91–596, Executive Order 12196, the requirements of 29 CFR 1960.59, and program requirements. The instruction will help to develop requisite skills in implementing safety programs within the work units, including training and motivating employees toward safe work practices and making them aware of their specific responsibilities in the programs.

Collateral duty safety personnel and Area Safety Committee members.—Upon appointment to a collateral duty safety position or to an Area Safety Committee, an employee will be provided with appropriate training commensurate with the scope of the assigned responsibilities. Such training must include NASA's Occupational Safety Program; Section 19 of Public Law 91–596 (the "Occupational Safety and Health Act"); Executive Order 12196; the requirements of 29 CFR 1960.59; NASA procedures for reporting, evaluating, and abating hazards; NASA procedures for reporting and investigating allegations of reprisal; recognition of hazardous conditions and environments; identification and use of occupational safety standards; and other appropriate rules and regulations.

Employee representatives.—Training for Lewis personnel who are representatives of employee groups, such as recognized bargaining units, will include information and materials that will enable such groups to ensure safe working conditions and practices in the workplace. Such instruction should enable these groups to effectively assist in conducting workplace safety inspections and monitoring the safety program's effectiveness.

Workplace employees.—Managers and supervisors are responsible for recognizing potential hazards in their areas and arranging for special training for workplace employees. Such training must include general information on the NASA safety programs, the Lewis safety programs, and the employees' roles and rights, and specific training relating to hazards in their particular workplace.

Two courses are mandatory for all new employees: "Lewis New Employee Safety Orientation" and "Federal Hazard Communications Training." They are available on videotape in the Learning Center.

2.7.4 Schedule

A comprehensive occupational safety and health training schedule for each new fiscal year will be published by the T&ATB with assistance from the SAO, OEP, and the Lewis Fire Department.

2.8 CATEGORIES OF POTENTIALLY HAZARDOUS OPERATIONS

2.8.1 Category I

Category I hazardous operations are those tasks that potentially have a high degree of immediate hazard to the operator or user, other employees, NASA equipment, facilities, or the public. Additional Category I tasks can be designated by a certifying authority or his/her appointee in a task area. The following personnel are involved in Category I tasks:

(a) Air crew members (FAA licensing may not be sufficient)

(b) Centrifuge subjects and operators

(c) Critical lift crane operators (critical to be determined by the installation in accordance with the replacement value, uniqueness of the material lifted, and the hazards involved)

(d) Firefighters

(e) Propellant or explosives users

(f) Propellant or explosives handlers

(g) Rescue personnel

(h) Self-contained atmospheric protective ensemble (SCAPE) users

(i) Self-contained underwater breathing apparatus (SCUBA) divers and other underwater divers

2.8.2 Category II

Category II operations are those tasks that, if not done correctly, could create a severe hazard to the operator or user, other personnel, and/or property. Category II operations can be designated by each of the certifying authorities; the following personnel are involved in Category II tasks:

(a) Altitude chamber operators

(b) Heavy equipment operators (e.g., forklift)

(c) High-pressure liquid/vapor/gas system operators (above 150 psig)

(d) High-voltage electricians (above 110 V)

(e) Confined space monitors

(f) Hyperbaric chamber operators

(g) Explosive-actuated tool operators

(h) Radiation (ionizing and non-ionizing) workers

(i) Tank farm workers

(j) Wind tunnel operators (if not covered by Safety Permit)

(k) Welders

(l) Hazardous material users (unless covered above in Category I)

(m) Crane operators (other than critical lift)

(n) Riggers for hoisting operations

2.8.3 Category III

Category III hazardous operations pertain strictly to operations of handling, transporting, or packaging hazardous materials without otherwise disturbing the basic, properly packaged shipping container that holds the hazardous material. Operations that involve the reduction of palletized, or otherwise combined, items of packaged hazardous materials qualify as handling.

2.9 CERTIFICATION REQUIREMENTS

All personnel engaged in potentially hazardous operations at the Category I, II, or III level, as determined by line management, the OEP, or the SAO, will be certified as capable to operate the equipment or perform their jobs in a safe manner if they meet the standards set forth here.

2.9.1 Category I

For Category I hazardous jobs, the following are minimum requirements for certification:

(a) Physical examination (see Sec. 2.9.4)

(b) On-the-job training

(c) Classroom training (for initial certification and as needed)

(d) Written and/or hands-on examination (as needed)

(e) Issuance of a certification card or listing on a Certified Personnel Roster, NASA Form C-9874

(f) Annual retraining that will include review of emergency response procedures and first aid procedures

(g) Periodic Category I recertification as determined by the certifying authority and the SAO (not to exceed a 4-year interval)

2.9.2 Category II

For Category II hazardous jobs, certification requirements should be similar to those of Category I (Sec. 2.9.1) except for appropriate reductions in the levels of examination, training, and testing, to be consistent with the lower potential hazard levels of Category II jobs. Certification requirements are left to the discretion of each certifying authority, with the approval of the SAO.

2.9.3 Category III

For Category III hazardous jobs, the following are minimum requirements for certification:

(a) Specific training in Federal, NASA, and local rules for preparing, packaging, marking, and transporting hazardous materials associated with the job

(b) Examination by written test to determine the adequacy and retention of the training

(c) Issuance of a card or license (to be carried on person) listing name, date, materials for which certification is valid, signature of certifying official, and date of expiration

(d) Periodic Category III recertification as determined by the OEP and SAO, in the absence of any state or Federal requirements

2.9.4 Need for Physical Examination

Unless otherwise specified, the need for physical examinations for Category I and II jobs, either as a means to determine fitness for duty or to assist in establishing a baseline for occupational exposure level, will be determined by the Lewis Medical Officer and will be in compliance with the applicable codes, regulations, and standards covering the particular occupation or environment. The need for fitness-for-duty examinations should be based on the hazardous consequences if an employee should be unable to perform the job correctly because of physical or mental deficiencies.

2.10 CERTIFICATION PROCEDURES

To certify personnel to perform Category I, II, or III hazardous operations follow these steps:

(a) Line management (to facilitate tracking, this should be no lower than branch level) should submit the type of operation, category of hazardous operation, and certification requirements to the SAO for approval. NASA Form C-9875, Request for Certification of Personnel for Potentially Hazardous Operations, should be used for this submittal.

(b) The SAO will review the information to determine that the selected category is appropriate and that the certification requirements meet the minimum as set forth in this chapter. If the requirements do not meet the minimum, the SAO will consult with line management to reach an acceptable set of requirements.

(c) Line management will implement the requirements and document all actions by type, name and organization of employees involved, and date.

(d) The Technical and Administrative Training Branch, along with line management, will ensure that employee training records are updated to reflect successful completion of certification training.

(e) Line management will issue an Operators Card to the certified personnel (CP) or will maintain a roster (NASA Form C-9874) of CP's by operation. Operators Cards and Certified Personnel Rosters will be signed by the individual employee's manager or supervisor. Contractors who successfully complete the certification training will have their Operators Cards or Certified Personnel Roster signed by their respective managers. Personnel who fail to meet minimum certification requirements will be notified by line management for retraining and retesting.

(f) The SAO will audit the certification and documentation of training.

2.11 BIBLIOGRAPHY

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———Subch. C, Pt. 171, Sec. 8. Hazardous Materials Regulations. General Information, Regulations, and Definitions.

Chapter 3. ENVIRONMENTAL QUALITY

Chapter 3. ENVIRONMENTAL QUALITY

3.1 SCOPE

This chapter sets forth policies and requirements for the construction and operation of Lewis facilities that may contribute waterborne wastes to sewer systems, emit air contaminants to the atmosphere, or produce wastes that require offsite disposal. The provisions herein are in accord with the national effort to improve environmental quality through prevention, control, and abatement of pollution from Federal facilities.

3.2 APPLICABILITY

This chapter applies to all facilities of the Lewis Research Center at Cleveland and at the Plum Brook Station.

3.3 AUTHORITY

The authority for these policies and requirements comes from the following:

(a) "Federal Water Pollution Control Act" (33 U.S.C. 1251 et seq.)

(b) "Air Pollution Prevention and Control Act" (42 U.S.C. 7401 et seq.)

(c) "Resource Conservation and Recovery Act" (42 U.S.C. 6901 et seq.)

(d) "Comprehensive Environmental Response, Compensation, and Liability Act" (42 U.S.C. 9601 et seq.)

(e) "Toxic Substances Control Act" (15 U.S.C. 2601 et seq.)

(f) "National Environmental Policy Act" (42 U.S.C. 4321 et seq.)

(g) Executive Order 12088, "Federal Compliance with Pollution Control Standards"

(h) LMI 8800.4, "Lewis Environmental Quality Program"

(i) LMI 1703.1, "Safety Permits"

(j) LMI 8800.5, "Preparation and Review of Environmental Assessments"

3.4 POLICY

It is the policy of the Lewis Research Center to comply with all applicable regulatory standards in carrying out its mission and to provide technical leadership in protecting and enhancing the quality of the environment.

3.5. RESPONSIBILITIES

The organizational responsibilities for environmental protection are fully spelled out in LMI 8800.4, "Lewis Environmental Quality Program." The following paragraphs briefly describe the responsibilities of certain organizations and individuals.

3.5.1 Environmental Pollution Control Board

The Environmental Pollution Control Board (EPCB) sets Lewis environmental policy and serves as the Center's environmental decision-making board. The EPCB serves as an appeal channel for unresolved questions pertaining to the environmental impact of Lewis operations.

3.5.2 Office of Environmental Programs

The Office of Environmental Programs (OEP) is responsible for recognizing, measuring, and recommending control of hazardous factors in the work environment. The OEP implements policies formulated by the EPCB.

3.5.3 Facilities Operations Division

The Facilities Operations Division is responsible for physical operation and maintenance of the process water systems and the industrial waste system at the Cleveland Center. This responsibility includes oil separator pit maintenance, oil skimming operations, emergency spill containment, and sludge removal. These functions are performed at the Plum Brook Station by the support services contractor's Technical Services Group.

3.5.4 Fire Department

At the Cleveland Center, the Lewis Fire Department assists in operational surveillance and is the focal point of communications in initiating emergency spill containments and cleanup plans. At Plum Brook Station the support service contractor's Plant Protection Group performs this function.

3.5.5 Building Managers

Building Managers are trained in appropriate environmental requirements and serve as monitors of the area to help ensure that these requirements are being met. This includes, specifically, making periodic checks on the waste disposal dumpsters and scrap-metal hoppers. Any questions or comments concerning other requirements will be directed to the Office of Environmental Programs.

3.5.6 Individuals

It is the responsibility of each employee, whether civil servant or contractor, to use common sense and be familiar with requirements applicable to his/her work area so as to ensure that the operations of the Center do not have any unnecessary adverse impact on the environment.

Any person who becomes aware of any spill or any inadvertent or unauthorized release of toxic or hazardous materials shall report the incident by dialing 911.

3.6 REQUIREMENTS FOR DESIGN AND CONSTRUCTION

All facilities shall be designed and constructed in accordance with the criteria and standards set fourth in the authorities cited in this chapter. In addition, these facilities shall comply with local, state, and Federal regulations and codes that apply to protection of the environment.

The assessment of environmental impact and evaluation of design, construction, and modification activities shall be done in the initial planning stages. Requirements governing such assessments are contained in LMI 8800.5, "Preparation and Review of Environmental Assessments and Environmental Impact Statements."

Except for domestic type sewage originating at standard plumbing fixtures, all designs, whether for new facilities or for modifications to existing facilities, in which connections are to be made to any Lewis waterborne waste disposal system or in which new discharges are to be released into the atmosphere shall be submitted for review, evaluation, and approval by the Office of Environmental Programs (OEP) and the Process Systems Safety Committee. Approval shall be reflected in the issuance of a Safety Permit and shall be secured before procurement, installation, or modification is initiated.

3.7 REQUIREMENTS FOR OPERATION AND MAINTENANCE

3.7.1 Facilities

Facilities will be operated and maintained so as to achieve compliance with the standards described in Section 3.6 and with regulations issued by the authorities cited in Section 3.3. The line management responsible for an operation is also responsible for ensuring that these requirements are met. The OEP can provide guidance about the required permits, discharge limitations, and other standards.

3.7.2 Disposal of Nonradioactive Hazardous Substances

A number of collection sites throughout the Center have been established for the segregated collection of waste oils and hazardous solvents. The wastes at these sites are picked up at least every 90 days by the hazardous waste management group of the OEP. When making a pickup, this group also leaves empty drums for waste collection.

The Building Manager for each area (at Plum Brook, the site supervisor) is responsible for performing weekly inspections of the waste collection areas to ensure that drums are properly labeled and in good condition. The OEP will provide the necessary forms and training to enable the Building Manager to perform this function. It is the responsibility of the Building Manager to attend the required training.

A NASA Form C-260 is used to arrange for disposal of any hazardous waste generated outside the normal course of business. All such wastes must be disposed of within 90 days of their generation. The organization in charge of a project is responsible for making arrangements in advance for wastes that may be generated and for inspecting the wastes prior to their shipment offsite.

3.7.3 Disposal of Radioactive Waste

Disposal of any radioactive waste will be coordinated and overseen by the Health Physics Office. It is the responsibility of the group generating radioactive wastes to make arrangements with the Health Physics Office beforehand to ensure proper handling, storage, and transportation.

3.8 BIBLIOGRAPHY

Executive Order 12088. U.S. Code Congressional and Administration News. 1978. Federal Compliance With Pollution Control Standards.

LMI 1703.1. NASA Lewis Research Center Management Instructions. Safety Permits.

LMI 8800.4. NASA Lewis Research Center Management Instructions. Lewis Environmental Quality Program.

LMI 8800.5 NASA Lewis Research Center Management Instruction. Preparation and Review of Environmental Assessments and Environmental Impact Statements.

Title 15, U.S. Code, Sec. 2601 et seq. Toxic Substances Control Act.

Title 33, U.S. Code, Sec. 1251 et seq. Federal Water Pollution Control Act.

Title 42, U.S. Code, Sec. 4321 et seq. National Environmental Policy Act.

———Sec. 6901 et seq. Solid Waste Disposal. Resource Conservation and Recovery Act.

———Sec. 7401 et seq. Air Pollution Prevention and Control Act.

———Sec. 9601 et seq. Comprehensive Environmental Response, Compensation, and Liability Act.

Chapter 4. HAZARDOUS MATERIALS

Chapter 4. HAZARDOUS MATERIALS

4.1 SCOPE

This chapter is organized to consider the safety aspects of potentially hazardous materials and to direct employees to information on such toxic chemicals as carcinogens, solvents, propellants, mercury, asbestos, beryllium, lead, and any other hazardous chemicals identified by the Occupational Safety and Health Administration, the Environmental Protection Agency, and other sources. This chapter will also identify Lewis functional organizations that can assist in assessing the safety hazards of working with hazardous materials, and in providing engineering controls, guidance, training requirements, personal protective equipment, and general safety practices.

4.2 DEFINITIONS

(a) Hazardous material. "A substance or material in a quantity or form which may pose an unreasonable risk to health and safety or property when transported in commerce" (49 CFR 171.8). The Secretary of Transportation has developed a list of hazardous materials, which may be found in 49 CFR 172.101. Typical hazardous materials are those that may be highly reactive, poisonous, explosive, flammable, combustible, corrosive, radioactive, or carcinogenic, or those that contaminate or pollute the environment, or cause adverse health effects or unsafe conditions. Regulation 29 CFR 1910.1000, "Toxic and Hazardous Substances," lists those chemicals held to be hazardous.

(b) Physical hazard. A chemical or product that has been scientifically established to be a combustible liquid, a compressed gas, an organic peroxide, or an oxidizer, or that is explosive, flammable, pyrophoric, unstable (reactive), or water reactive.

(c) Material Safety Data Sheet (MSDS). A document, provided by the manufacturer or importer of a hazardous chemical or prepared by Lewis researchers, that identifies a hazardous material and provides information about the physical and health hazards associated with it. (See samples of MSDS's in the appendix.) Note that all MSDS's are not necessarily alike; however they must contain certain key information, which includes the following: product identification, manufacturer's name and address, hazardous ingredients information, physical and chemical characteristics, fire and explosion hazard data, reactivity data, health hazard data, precautions for safe handling and use, and control measures.

Additional information on MSDS's can be found in the "Material Safety Data Sheet Dictionary," which includes over 300 terms commonly found in MSDS's and abbreviations, acronyms, and synonyms, along with explanations of the various sections found in an MSDS.

(d) Carcinogen. A chemical to which any of the following apply:

- It has been evaluated by the International Agency for Research on Cancer (IARC) and found to be a carcinogen or potential carcinogen.

- It is listed as a carcinogen or potential carcinogen in the latest edition of "Annual Report on Carcinogens" published by the National Toxicology Program.

- It is regulated by OSHA as a carcinogen.

(e) Highly toxic. A chemical falling within any of the following categories:

- A chemical that has a median lethal dose (LD50) equal to or less than 50 milligrams per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

- A chemical that has an LD50 equal to or less than 200 milligrams per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs with 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each.

- A chemical that has an LD50 in air equal to or less than 200 parts per million by volume of gas or vapor, or an LD50 equal to or less than 2 milligrams per liter of mist, fume, or dust when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 grams each.

4.3 APPLICABILITY

The provisions of this chapter apply to all hazardous materials used at the Cleveland Center and Plum Brook Station.

4.4 POLICY

It is Center policy that an employee's health and safety is the highest priority; therefore, all Lewis, tenant, and resident support services contractor employees who handle, store, transport, use, produce, or dispose of hazardous materials must be informed of the hazards of the chemicals with which they work so that they can take appropriate measures to protect themselves from the hazards, minimize exposures to the chemicals, and work with materials in a safe and healthful manner.

4.5 RESPONSIBILITIES

All employees located at the Cleveland Center and the Plum Brook Station who use, store, handle, dispose of, or modify by reaction with hazardous materials are responsible for understanding and conforming with the guidelines, safe practices, and provisions of this chapter. Specific individuals or organizations are responsible for establishing safety requirements for hazardous materials. These organizations and their responsibilities follow:

4.5.1 Executive Safety Board

See LMI 1702.1, for the responsibilities of the ESB.

4.5.2 Area Safety Committees

The responsibilities of the Area Safety Committees are given in LMI 1702.

4.5.3 Environmental Pollution Control Board

LMI 8800.4 details the responsibilities of the Environmental Pollution Control Board.

4.5.4 Office of Environmental Programs

The Office of Environmental Programs (OEP) is responsible for managing, directing, and implementing the environmental programs of the Center and has functional management of the Lewis Hazard Communication Program, which identifies and controls the handling, storage, and use of potentially hazardous materials at Cleveland and Plum Brook.

4.5.5 Hazardous Chemicals Office

The Hazardous Chemicals Office is responsible for implementing the Lewis Hazard Communication Program, for ensuring that appropriate hazard awareness training is provided to Center employees, and for maintaining inventory control of hazardous chemicals purchased by the Center as stock items and program chemicals. It provides technical support on the hazards of materials, their handling, storage, and use, and on the safety measures necessary to protect the employee from the hazards of the materials. It also provides Material Safety Data Sheets (MSDS's) to employees who work with hazardous chemicals.

4.5.6 Employees

Procedures for purchasing and disposing of chemicals are found in LMI 5104.3, "Acquisition of Chemicals and Hazardous Materials," and LMI 1701.2, "Disposal of Hazardous Materials and Wastes." Employees are reminded not to buy more chemicals than they can possibly use in their project and not to stockpile material. Employees are to budget for the disposal of their chemicals and hazardous wastes when there is no longer a use for the material.

4.6 GENERAL INFORMATION

It is prudent to consider all chemicals hazardous until proven otherwise. Chemicals occur in three physical states—solids, liquids, and gases—and can be dangerous in all three states. Information on the physical and chemical characteristics of any chemical can be obtained from the manufacturer's MSDS and also from the labels found on the containers.

It must be noted that labels may become damaged, defaced, or evan fall off as the container is used, so the hazards of the material may not be immediately known to the label reader. The person working with the material will need to refer to the appropriate MSDS for the information.

MSDS binders containing MSDS's of NASA Stock Chemicals are located in every building at the Center. Employees are required to know where they are located and to become familiar with their contents. **Employees who work with chemicals that are not stock items are required to obtain MSDS's for all such chemicals and maintain a file of those MSDS's in their work area.** Copies of MSDS's may be obtained by calling the Hazardous Chemicals Office (PABX 8689) or the Chemical Management System (PABX 2124).

Laboratory Safety is covered in Chapter 13 of the Lewis Safety Manual. The Center's Chemical Hygiene Policy is found in LMI 8710.2, which covers compliance with OSHA Standard 29 CFR 1910.1450, "Occupational Exposure to Hazardous Chemicals in Laboratories." In general, one should work with laboratory quantities of hazardous chemicals in well-ventilated fume hoods; use appropriate protective clothing, goggles or face shields, impervious gloves, and respirators when required; and follow good personal hygiene practices by washing thoroughly after handling any chemicals. Eating and smoking in the workplace is not permitted.

4.6.1 Flammable Liquids and Gases

Flammable materials shall be kept away from ignition sources or open flames, and containers shall be bonded to the building grounding system when a flammable material is being transferred to a secondary container or another system such as a test facility. Flammables shall be stored in metal safety cans that are properly labeled and equipped with flame arresters, and placed into flammable-storage cabinets. At no time should flammables be stored in basement areas or below grade locations, per National Fire Protection Association Codes. Explosion-proof electrical fixtures shall be used in areas where flammables are stored or handled. (See NFPA 70, "National Electric Code" for specific requirements.)

4.6.2 Toxic and Carcinogenic Chemicals

Chemicals known to be highly toxic or carcinogenic (see DEFINITIONS, Sec. 4.2) should be stored in well-ventilated storage areas in unbreakable, chemically resistant secondary containers. Only minimum quantities of toxic materials, sufficient to work with on a daily basis, should be present in the work area. Consult with the Chemical Hygiene Officer (PABX 8689) about maximum allowable quantities in the work area.

Storage containers should carry a label with the following:

HIGH CHRONIC TOXICITY or CANCER-SUSPECT AGENT

Storage areas for materials that can cause highly acute or chronic toxicity should exhibit a proper hazard warning sign, be of limited access, and be adequately ventilated. An inventory of the toxic chemicals and of those regulated as a carcinogen should be maintained and posted at the site as required by the Lewis Hazard Communications Program. Specific instructions on working with **asbestos** and **mercury** can be found in LMI 1800.1 and LMI 8800.4 respectively. Check the MSDS's for specific hazards associated with the materials that you may be exposed to and take the necessary precautions to protect yourself and others from unnecessary exposure to toxic and carcinogenic materials. Also review the references listed in this chapter for additional information. They are excellent sources of information.

4.7 REPORTING EMERGENCIES

Any person who becomes aware of any spill or the inadvertent or unauthorized release of toxic or hazardous materials to the environment shall report the incident and obtain help by dialing 911 on a PABX phone at Lewis or on a PBX phone at the Plum Brook Station. At no time should anyone try to clean up a spill without help.

4.8 HAZARD COMMUNICATION (HAZCOM) TRAINING

4.8.1 Employees

All Center employees, including resident support service contractors, are required to attend Hazard Communication Awareness Training. Employees who work in chemical laboratories are further required to attend Chemical Hygiene Awareness Training. This training is conducted by the Hazardous Chemicals Office and coordinated by the Training and Development Branch.

4.8.2 Supervisors

Supervisors are responsible for training their employees in the specific hazards of chemicals that the employee will use and for documenting such training, as required by LMI 8710.1, "Lewis Hazard Communication Policy and Responsibilities."

Allied Signal

PRODUCT SAFETY DATA SHEET

GENETRON® 114 dichlorotetrafluoroethane

SAMPLE

A. GENERAL INFORMATION

TRADE NAME (COMMON NAME)
GENETRON® 114 dichlorotetrafluoroethane

C.A.S. NO. ☐ ALLIED PRODUCT CODE #
5-14-2

CHEMICAL NAME AND/OR SYNONYM
Dichlorotetrafluoroethane Synonyms: Fluorocarbon 114; Pro-

FORMULA
$CClF_2CClF_2$

MOLECULAR WEIGHT
170.92

ADDRESS (N-

ALLIED-SIGNAL INC.
Engineered Materials Sector
P.O. Box 1139R
Morristown, N.J. 079-

CONTACT
Product Safety Dep

PHONE NUMBER	LAST ISSUE DATE	CURRENT ISSUE DATE
(201) 455-4157	October, 1985	May, 1988

B. FIRST AID MEA-

EMERGENCY PHONE NUMBER
(201) 455-2000

Inhalation: Immediately remove to fresh air. If breathing has stopped, give artificial respiration, preferably mouth-to-mouth. Use oxygen as required, provided a qualified operator is available. Call a physician. Do not give epinephrine (adrenaline).

Skin or Eye Contact: Immediately bathe any frostbite (do not rub) with lukewarm (not hot) water. In the absence of water, cover with soft wool or other suitable material. Contact a physician for any low temperature burns from liquid contact.

Ingestion: This is highly unlikely due to the low boiling point (circa 38°F) and gaseous state at normal temperature and pressure.

C. HAZARDS INFORMATION

HEALTH

INHALATION
Vapors are relatively nontoxic but may act as a narcotic and CNS depressant at high concentrations (when oxygen levels in air are reduced to 12 - 14%). Symptoms of asphyxiation may occur, namely: loss of coordination, increased pulse rate, deeper respiration, nausea and dizziness. Epinephrine may sensitize the myocardium to this substance.
See Section K for further discussion and results of animal sutdies, including cardiac sensitization.

INGESTION
Not pertinent, since material is gaseous at normal temperature and pressure.

SKIN
Contact of liquid material with skin may cause frostbite, indicated by pallor or redness, loss of sensation and swelling of affected tissue.

EYES
Same effect from liquid contact as for skin.

PERMISSIBLE CONCENTRATION: AIR (SEE SECTION J) OSHA/TWA: 1000 ppm
ACGIH/TLV: the same.

BIOLOGICAL
No established value found.

UNUSUAL CHRONIC TOXICITY
None known, based on available data.

CC124-404 (11/84) ND = NOT DETERMINED 1 NA = NOT APPLICABLE

C. HAZARDS (Cont.)

FIRE AND EXPLOSION

FLASH POINT N.A. °C	AUTO IGNITION TEMPERATURE °C	FLAMMABLE LIMITS IN AIR (% BY VOL.)
Non-flammable ☐ OPEN CUP ☐ CLOSED CUP	Not applicable	LOWER – Not applicable UPPER – Not applicable

UNUSUAL FIRE AND EXPLOSION HAZARDS
Containers may rupture violently in fire due to overpressure, releasing large quantities of gas or vapor. Contact with certain other chemicals may result in formation of explosive mixtures. See Section G, Hazardous Decomposition Products and Materials to Avoid.

D. PRECAUTIONS/PROCEDURES

FIRE EXTINGUISHING AGENTS RECOMMENDED

Material itself is non-flammable. Choose any standard agent appropriate for the type of surrounding fire.

FIRE EXTINGUISHING AGENTS TO AVOID

Any standard agent may be used.

SPECIAL FIRE FIGHTING PRECAUTIONS

When this material is involved in a fire, firefighters should wear self-contained breathing apparatus, approved by NIOSH, for protection against suffocation and possible toxic decomposition products. Use water spray to keep fire-exposed containers cool.

VENTILATION

Ventilation should be adequate to meet TWA/TLV requirements and minimize exposure.
Provide local exhaust at filling zones and where leakage is probable.
Mechanical (General) ventilation is adequate for other operating and storage areas.

NORMAL HANDLING

Avoid liquid contact with eye, skin or clothing. Do not puncture or drop cylinders or expose them to open flame or excessive heat. Use authorized containers only. Follow standard safety precautions for handling and use of cylinders of compressed gases – Reference (c).

STORAGE

Store in a cool, dry, well-ventilated area away from heat or flame. Protect cylinder and its fittings from physical damage. Storage in subsurface locations should be avoided. See Reference (c) for further details on storage.

SPILL OR LEAK (ALWAYS WEAR PERSONAL PROTECTIVE EQUIPMENT – SECTION E)

Using a self-contained air supply and protection against frostbite, involved personnel should attempt to close valves or repair source of leak.
If a large quantity is released, evacuate personnel and allow to dissipate. (Note Section C for health hazards involved with inhalation and contact exposure.)
Any release to the environment of this material may be subject to federal and/or state reporting requirements. Check with appropriate agencies.

SPECIAL PRECAUTIONS/PROCEDURES/LABEL INSTRUCTIONS SIGNAL WORD – WARNING!

This product can cause serious personal injury, or death, if not handled properly. Follow OSHA regulations for compressed gases – Reference (4), and Reference (c) for cylinder handling.

E. PERSONAL PROTECTIVE EQUIPMENT

RESPIRATORY PROTECTION

None generally required for adequately vented situations. For unusual situations, where concentrations exceed TWA/TLV, wear a self-contained breathing apparatus or supplied-air respirator, approved by NIOSH. At high concentrations, add a full facepiece.

EYES AND FACE

For normal conditions, wear safety glasses. Where there is reasonable probability of liquid contact, wear chemical safety goggles. Contact lenses should not be worn under such conditions.

HANDS, ARMS, AND BODY

Wear protective gloves of PVA or neoprene and impervious shoes and clothing where leakage and liquid contact are probable. Thermal insulation to prevent frostbite is recommended.

OTHER CLOTHING AND EQUIPMENT

Provide convenient water source for first-aid treatment in case of frostbite (see Section B).

F. PHYSICAL DATA

MATERIAL IS (AT NORMAL CONDITIONS):	APPEARANCE AND ODOR	
☐ LIQUID ☐ SOLID ☒ GAS ☐ ____________	Colorless liquid which rapidly evaporates; practically odorless.	
BOILING POINT 3.55 °C MELTING POINT −94 °C	SPECIFIC GRAVITY (H_2O = 1) (Liquid) 1.465	VAPOR DENSITY (AIR = 1) 5.9
SOLUBILITY IN WATER (% by Weight) 0.013	pH Unknown. Estimated to be neutral.	VAPOR PRESSURE (mm Hg at 20°C) ☐ (PSIG) ☒ 12.9 @ 21.1°C
EVAPORATION RATE (Butyl Acetate = 1) ☐ (Ether = 1) ☒ (Time to evaporate) Less than 1	% VOLATILES BY VOLUME (At 20°C) 100	

G. REACTIVITY DATA

STABILITY	CONDITIONS TO AVOID
☐ UNSTABLE ☒ STABLE	High temperatures, lighted cigarettes, flames, hot spots, welding. These conditions cause decomposition to form toxic, corrosive gases.

INCOMPATIBILITY (MATERIALS TO AVOID)

Freshly abraded aluminum surfaces: cause strong exothermic reaction — Reference (e).
Chemically active metals: sodium, potassium, calcium. Powdered aluminum, zinc, and magnesium — Reference (f).

HAZARDOUS DECOMPOSITION PRODUCTS

Halogens, halogen acids and possibly carbonyl halides, such as phosgene. These are toxic and corrosive.

HAZARDOUS POLYMERIZATION	CONDITIONS TO AVOID
☐ MAY OCCUR ☒ WILL NOT OCCUR	None known.

H. HAZARDOUS INGREDIENTS (Mixtures Only)

MATERIAL OR COMPONENT/C.A.S. #	WT. %	HAZARD DATA (SEE SECT. J)
NOT APPLICABLE.		

CC124-404 (11/84) * = PROPRIETARY – TRADE SECRET

I. ENVIRONMENTAL

DEGRADABILITY/AQUATIC TOXICITY	OCTANOL/WATER PARTITION COEFFICIENT
	N.A. – 100% volatile

Degradability (BOD): No data found but it is not considered to be biodegradable (100% volatile gas).

Aquatic Toxicity: No data found.

EPA HAZARDOUS SUBSTANCE? (CLEAN WATER ACT SECT. 311)	IF SO, REPORTABLE QUANTITY:	40 CFR 116-117
☐ YES ☒ NO	— #	

WASTE DISPOSAL METHODS (DISPOSER MUST COMPLY WITH FEDERAL, STATE AND LOCAL DISPOSAL OR DISCHARGE LAWS)

Disposal of GENETRON® 114, if used as a solvent, may be subject to federal, state and local regulations (EPA spent chlorinated fluorocarbon solvent – F001). Users should review their operations in terms of applicable federal, state and local laws and regulations, then consult with appropriate regulatory agencies before discharging or disposing of waste material.

RCRA STATUS OF UNUSED MATERIAL IF DISCARDED:	HAZARDOUS WASTE NUMBER: (IF APPLICABLE)	40 CFR 261
Not a "hazardous waste" if discarded unused.	N.A.	

J. REFERENCES

PERMISSIBLE CONCENTRATION REFERENCES

(1) OSHA/TWA: OSHA regulation 29 CFR 1019 (1982), "Z List".
(2) ACGIH/TLV: 1987-88 List, "Threshold Limit Values and Biological Exposure Indices".
(3) NIOSH Registry (RTECS), 1981-82, Accession No. KI1101000.

REGULATORY STANDARDS	D.O.T. CLASSIFICATION: Not regulated	49 CFR 173

(4) OSHA regulations for compressed gases: 29 CFR 1910.101.

GENERAL
(a) ACGIH: Documentation of TLVs, 4th edition.
(b) Matheson Gas Data Book, 5th ed., 1971, Matheson Gas Products, E. Rutherford, NJ.
(c) CGA Pamphlet P-1, "Safe Handling of Compressed Gases in Containers", 6th ed., 1980 printing, Compressed Gas Association, NYC 10036
(d) Aviado, D.M., Toxicology 3, 1975, 321-332.

(continued – Section K)

K. ADDITIONAL INFORMATION

SECTION J – REFERENCES (General) – continued
(e) NFPA Manual, 491M, "Manual of Hazardous Chemical Reactions", 8th ed., 1984, National Fire Protection Assn., MA 02210.
(f) NIOSH: "Pocket Guide to Chemical Hazards", —1985, 5th printing.
(g) Reinhardt, C.F. et al., Arch. Envir. Health 22, 1971, 265-279.

SECTION C – HAZARDS INFORMATION (Health) – Inhalation (continued)
Inhalation of 1% caused slight irritation in guinea pigs. 2% to 4.7% caused distinct irritation and increased respiration, but no pathological changes after two hours. 20% by volume caused tremors and convulsions in dogs. Repeated 8-hour exposures @ 20% were fatal to dogs in 2 to 3 days – Reference (a).

Cardiac Effects: Cardiac arrhythmia (which can be fatal in animals and in man) has been produced in monkeys at 50,000 ppm, but 5-minutes' exposure of a mouse produced no effect at 400,000 ppm – Reference (d).**

** The probability of incurring cardiac arrhythmia is greatly increased by the presence of a second agent, epinephrine (adrenaline): inhalation of vapor at levels as low as 25,000 ppm can produce cardiac sensitization to epinephrine in dogs, resulting in cardiac arrhythmias that can be fatal – Reference (g).

PSDS FILE NO. 895

NASA
National Aeronautics and
Space Administration

Lewis Research Center
Cleveland, Ohio 44135

Date:

MATERIAL SAFETY DATA SHEET

SECTION I — PRODUCT IDENTIFICATION

PRODUCT NAME:
CAS NUMBER:
COMMON NAME(S):

MANUFACTURER'S NAME: NASA Lewis Research Center
ADDRESS: 21000 Brookpark Road
Cleveland, Ohio 44135

EMERGENCY TELEPHONE NUMBER: 216–433–2088
TELEPHONE NUMBER FOR INFORMATION:

DATE PREPARED:
SIGNATURE OF PREPARER *(optional)*:

SECTION II — HAZARDOUS INGREDIENTS INFORMATION

HAZARDOUS COMPONENTS	%	OSHA PEL	ACGIH TLV

This form must be used by NASA Lewis Research Center personnel to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements.

NOTE: Blank spaces are not permitted. If any item is not applicable or no information is available, the space must be marked to indicate that. Copy of completed form must be submitted to the Hazardous Chemicals Office.

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SECTION III — PHYSICAL AND CHEMICAL CHARACTERISTICS

BOILING POINT:
SPECIFIC GRAVITY (H_2O = 1):
VAPOR PRESSURE (mm Hg):
VAPOR DENSITY (Air = 1):
MELTING POINT:
EVAPORATION RATE (Butyl acetate = 1):
SOLUBILITY IN WATER (%):
APPEARANCE AND ODOR:

SECTION IV — FIRE AND EXPLOSION HAZARD DATA

FLASH POINT *(Method used)*:
FLAMMABLE LIMITS
LEL:
UEL:

NFPA RATING
HEALTH:
FLAMMABILITY:
REACTIVITY:

EXTINGUISHING MEDIA:

SPECIAL FIRE FIGHTING PROCEDURES:

UNUSUAL FIRE AND EXPLOSION HAZARDS:

SECTION V — REACTIVITY DATA

STABILITY: ☐ Stable ☐ Unstable
CONDITIONS TO AVOID:

INCOMPATIBILITY *(Materials to Avoid)*:

HAZARDOUS DECOMPOSITON OR BYPRODUCTS:

HAZARDOUS POLYMERIZATION: ☐ Will not occur ☐ May occur
CONDITIONS TO AVOID:

NASA-C-10007 (5-90) (continued)

SECTION VI — HEALTH HAZARD DATA

ROUTES OF ENTRY:

EYE:	☐ Yes	☐ No
SKIN:	☐ Yes	☐ No
INHALATION:	☐ Yes	☐ No
INGESTION:	☐ Yes	☐ No

ACUTE HEALTH HAZARDS

EYE CONTACT:

SKIN CONTACT:

INHALATION:

INGESTION:

CHRONIC HEALTH HAZARDS:

CARCINOGENICITY

NTP?	☐ Yes	☐ No
IARC?	☐ Yes	☐ No
OSHA REGULATED?	☐ Yes	☐ No

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE:

EMERGENCY AND FIRST AID PROCEDURES

EYE CONTACT:

SKIN CONTACT:

INHALATION:

INGESTION:

SECTION VII — PRECAUTIONS FOR SAFE HANDLING AND USE

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED:

WASTE DISPOSAL METHOD:

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORING:

OTHER PRECAUTIONS:

SECTION VIII — CONTROL MEASURES

RESPIRATORY PROTECTION *(Specify type)*:

VENTILATION:

PROTECTIVE GLOVES:

EYE PROTECTION:

OTHER PROTECTIVE CLOTHING OR EQUIPMENT:

WORK/HYGIENE PRACTICES:

4.10 BIBLIOGRAPHY

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DATA BASES—In addition to the reference texts listed and MSDS data bases supplied by a number of chemical manufacturers, two are available on the STN International Network, which can be accessed by the Lewis Library. These are

(1) CHEMLIST

Produced by the American Petroleum Institute, this data base contains information about chemical substances currently listed in the EPA's Toxic Substances Control Act (TSCA) Inventory or those compounds which are subject to TSCA or similar legislation. There are approximately 76,000 records in this file, created in 1979. Included in the file is a listing of references and abstracts for these records.

(2) CSNB

The Chemical Safety News Base, created in 1981 by the Royal Society of Chemistry in London, contains about 21,000 records on the environmental, health, and safety aspects of a variety of chemical substances. Specific information includes data on fires and explosions, storage, toxic substances, laboratory toxicology studies, and waste removal. Like the CHEMLIST data base, the information contained in CSNB is in the form of a bibliography that contains a reference and an abstract of that reference.

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LIST OF TABLES

Where precisely quantifiable direction is not possible, oxygen system design, material selection, and operating practice guidelines are based on proven experience and technical judgement.

The references listed in Section 5.13 are an essential part of this chapter. Knowledge of and adherence to these references is mandatory.

For definitions, see the Glossary in appendix D of Chapter 6; it applies to oxygen also.

5.2 POLICY

Liquid and gaseous oxygen shall be stored, handled, and used so that life and health are not jeopardized and the risk of property damage is minimized. Oxygen system design shall be done by experienced engineers with line management oversight.

5.2.1 Hazard Elimination: A NASA Directive

The primary consideration for resolving oxygen hazards shall be to **eliminate them by proper design** (see NHB-1700.1, "NASA Basic Safety Manual"). Hazards that **cannot** be eliminated by design shall be controlled by taking the following corrective actions in this order of precedence and by using the principles in Section 5.2.2.

(a) Designing for minimum hazard

(b) Installing safety devices

(c) Installing caution and warning devices

(d) Developing administrative controls, including special procedures and training

(e) Providing protective clothing and equipment

5.2.2 Approach to Oxygen Safety

The following design principles shall be adopted to achieve maximum oxygen safety at Lewis. It is assumed that the designer will employ standard analytical methods in the process of design.

<u>Inherent safety</u>.—Oxygen systems and operations shall have a high degree of built-in safety. The selection of materials that are ignition- and combustion-resistant at the maximum expected operating conditions and the suitable design of components and systems are essential. Safe oxygen systems must include special designs for preventing leaks, eliminating ignition sources, maintaining a clean system, avoiding cavitation, and preventing resonant vibration.

<u>Two lines of defense</u>.—In addition to the inherent safety features, at least two failure-resistant, independent barriers shall be provided to prevent a given failure from mushrooming into a disaster. Thus, at least two undesirable, independent events would have

to occur simultaneously under either normal or emergency conditions before there would be a potential danger to personnel or major damage to equipment and property.

Fail-safe design.—The equipment, power, and other system services shall be designed and verified for safe performance in the normal and maximum designed operational regimes. Any failures shall cause the system to revert to conditions that are safest for personnel and that will cause the least property damage. Redundant components shall be incorporated into the design to prevent shutdowns.

Automatic safety devices.—System safety valves, flow regulators, and equipment safety features shall be installed to automatically control hazards.

Caution and warning systems.—Warning systems to monitor those parameters of the storage, handling, and use of oxygen that may endanger personnel and cause property damage shall be incorporated into oxygen system design. Warning systems shall consist of sensors to detect abnormal conditions, to measure malfunctions, and to indicate incipient failures. Data transmission systems for caution and warning systems shall have sufficient redundancy to prevent any single-point failure from disabling an entire system.

Formal procedures.—All oxygen operations shall be conducted by knowledgeable, trained, and certified personnel following formal procedures. Personnel involved in design and operations will carefully adhere to the safety standards of this chapter and must comply with regulatory codes.

Personnel training.—Personnel assigned to handle/use liquid and gaseous oxygen or to design equipment for oxygen systems must become thoroughly familiar with the physical, chemical, and hazardous properties of oxygen.

Operator certification.—Operators shall be certified as "qualified" to handle liquid and gaseous oxygen and as "qualified" in the emergency procedures for handling leaks and spills according to Section 5.12.2 of this chapter.

Safety review.—At a minimum, all oxygen design, handling, and test operation activities shall be subject to an independent, third-party safety committee review and subject to a permit issued by that Area Safety Committee.

5.3 BASIC CONCEPTS AND GUIDELINES

Safe use of oxygen requires the control of potential ignition energy mechanisms within oxygen systems by judiciously selecting ignition-resistant **materials** (Sec. 5.9) and system **designs** (Sec. 5.10), maintaining scrupulously **clean** systems (Sec. 5.11), and using appropriate **operational procedures** (Sec. 5.12).

Safe operation with oxygen can be enhanced by understanding the following basic concepts:

(a) Oxygen can react with nearly all materials that are not already fully oxidized.

(b) The major hazards of liquid and gaseous oxygen are the possibilities of intense fires or explosions.

(c) A facility-wide fire hazard always exists when a major oxygen leak occurs. Nearby personnel, equipment, and buildings may readily ignite and burn in an oxygen-enriched atmosphere.

5.3.1 Managing the Oxygen Hazard

The oxygen hazard can be managed by

(a) Minimizing the severity of the environment (i.e., the system's operating parameters and practices)

(b) Using materials and designs best able to withstand the environment

Generally, using as many as possible of the following steps in concert minimizes the overall probability of a significant incident (ASTM Committee G4.05).

Minimizing the severity of the environment.—The environmental severity can be controlled by reducing the mechanisms that cause fires or add to their consequences, for example, by

(a) Cleaning scrupulously and maintaining this cleanliness

(b) Adopting certain practices, such as opening valves slowly

(c) Using valves with flow capacity to limit downstream pressurization rates

(d) Using automated hardware (or isolating or shielding the hardware) to reduce personnel exposure

(e) Minimizing flow velocities

Fire resistant materials.—Using fire-resistant materials improves the system's ability to withstand its environment. Materials used in oxygen service should be selected based on the following criteria:

(a) Resistance to ignition (i.e., materials with high ignition temperatures, high ignition impact thresholds, etc., as measured by specific tests)

(b) Resistance to propagation (i.e., materials that are either inherently or situationally nonflammable)

(c) Limitation of heat release and, therefore, limitation of destructive potential

Because so many variables are involved, there is no unique oxygen-service material. Numerous alternatives exist; therefore it is difficult to choose among vendors and/or companies with widely differing approaches and with results that may not meet expectations.

5.3.2 Waiver Provisions

In some instances the importance and urgency of a research program warrants some risk to property. These cases shall be referred, with recommendations and qualifications, to the Executive Safety Board for approval.

5.4 PROPERTIES OF OXYGEN

Liquid oxygen used as an oxidizer in propellant systems shall conform to MIL-P-25508E, Type II. Propellant grade liquid oxygen contains a minimum of 99.5 percent oxygen; the major impurity is argon. Gaseous oxygen used to purge and pressurize propellant systems shall conform to MIL-P-25508E, Type I or Fed. Spec. BB O-925A. Properties for breathing oxygen are specified in MIL-O-27210F.

5.4.1 Physical Properties

Oxygen is an element which, at atmospheric temperatures and pressures, exists as a colorless, odorless, and tasteless gas. High purity liquid oxygen is a light blue, transparent liquid. It is an extremely cold cryogenic fluid, which makes handling it potentially hazardous. It boils at -297 °F (90 K) at atmospheric pressure. It boils vigorously at ambient conditions. See table 5.1 for more information on the physical properties of oxygen.

5.4.2 Chemical Properties

Solubility.—Most common solvents are solid at liquid oxygen temperatures. Liquid oxygen is completely miscible with liquid nitrogen and liquid methane. Light hydrocarbons are usually soluble in liquid oxygen and **such mixtures are very hazardous.**

Reactivity.—In either gaseous or liquid form, oxygen is a strong oxidizer that vigorously supports combustion.

A material's rate of reaction with oxygen depends on the conditions of its exposure to oxygen and its physical and chemical properties. A particular material may react with oxygen at a rate ranging from very slow to explosive or detonatable.

5.5 OPERATIONAL HAZARDS OF OXYGEN

The oxygen hazard is subtle. Materials considered fireproof in air will burn violently in a pure oxygen environment. Oxygen-supported combustion of most engineering materials is a potential hazard. Some oxygen systems have given apparently normal service for decades before circumstances combine to yield an incident or fire.

One of oxygen's greatest hazards is its nonevident passive mixing with hydrocarbons. Once such a mixture is ignited, the reaction may proceed violently, even explosively.

The use of cryogenic oxygen can cause design and exposure problems.

5.5.1 General Hazards

The major hazards associated with operational use of liquid and gaseous oxygen are fire and explosion.

Ignition.—The ignition temperature of a material in oxygen systems is not an absolute physical property. It depends on many factors. To date, no single test has been developed that can be applied to all materials to produce absolute ignition temperature values. However, relative ranking and estimated ignition temperatures for many materials have been established through experimentation. Representative values are found in Chapter 3.4 of "Oxygen Systems Engineering Review" (Schmidt and Forney 1975).

Materials will ignite at considerably lower temperatures in oxygen environments than in air, and combustion rates are greater in oxygen than in air. Ignition occurs when a combustible material is heated to ignition temperature. The temperature rise could be from within the oxygen system, without any added energy from outside sources. Fluid friction, chemical reactions, adiabatic compression, or impact on container walls can produce sufficient energy for ignition to occur in oxygen systems.

Fire and explosion.—Oxygen supports vigorous or even explosive burning. Materials that burn only sluggishly or not at all in air burn quickly in oxygen. Almost any material will burn. For example, stainless steel, Teflon, and silicones, which are generally regarded as fire-proof or fire resistant, can burn easily in oxygen under the right conditions.

Some materials that can react violently with oxygen are oil, grease, asphalt, kerosene, cloth, wood, paint, tar, and dirt. Even many metals burn vigorously in gaseous oxygen. Violent fires in high-pressure oxygen systems have resulted from component failures, entrained metal particles in the flowing gas system, and rapid metal-to-metal contact within components.

Leaking or spilled liquid oxygen can form potentially dangerous, high concentrations of oxygen gas. In an oxygen-rich environment, clothing may become saturated with oxygen, ignite readily, and burn violently.

5.5.2 Cryogenic and Mixing Hazards

The very low temperature of liquid oxygen aids in condensing foreign matter and freezing out many impurities that may react with oxygen at a later time. Oxygen is easily contaminated because many gases and liquids are soluble in it and some are completely miscible. If an odorless and colorless gas is dissolved in oxygen, problems can result. In fact, inadvertent mixing of oxygen and a flammable gas can cause an explosion, and allowing argon or nitrogen to mix with and enter oxygen breathing systems can cause death.

There are other health hazards associated with the very low temperature of liquid oxygen. Frostbite results when such liquid or a noninsulated pipe containing it contacts the skin.

Breathing pure oxygen for limited periods of time (an hour or two) will not have any toxic effects; however, the upper respiratory tract may become irritated if the gas is very dry.

When liquid oxygen is trapped in a closed system and refrigeration is not maintained, pressure rupture may occur. Oxygen cannot be kept liquid if its temperature rises above the critical temperature of -181.4 °F (154.6 K).

5.6 OPERATIONAL SAFETY AND PROTECTIVE MEASURES

5.6.1 Safety Measures, Buddy System, and Written Procedures

All operations involving the handling of oxygen shall be performed under the buddy system (LMI 1704.1). The level of the buddy system required will vary with the hazard and complexity of the task, but shall never be lower than level "d" as defined in LMI 1704.1. At least two people are required at this level (see Ch. 13 of the Lewis Safety Manual). Other safety measures are as follows:

(a) Operators shall be certified as "qualified" according to Section 5.12.2 of this chapter.

(b) All operations involving oxygen shall be conducted by knowledgeable and trained personnel following formal written procedures.

(c) Consideration for the safety of personnel at and near oxygen storage and use facilities must start in the earliest planning and design stages.

Safety documentation made available to personnel should describe the safety organization and comment specifically on inspections, training, safety communications, operations safety, and accident investigations.

Training shall familiarize personnel with the nature of the facility's major process systems. Major systems include loading and storage systems; purge gas piping systems; control, sampling, and analyzing systems; alarm and warning signal systems; ventilation systems; and fire and personnel protection systems.

5.6.2 Personnel Training

Personnel who handle/use liquid and gaseous oxygen or who design equipment for oxygen systems must become familiar with its physical, chemical, and hazardous properties. In addition, the following requirements apply:

(a) Personnel must know which materials are most compatible with oxygen, what the cleanliness requirements of oxygen systems are, how to recognize system limitations, and how to respond to failures. Designated operators shall be familiar with procedures for handling spills and with the actions to be taken in case of fire.

(b) Training should include detailed safety programs for recognizing human capabilities and limitations. Instruction on the use/care of protective equipment and clothing shall be provided. Regularly scheduled fire drills and safety meetings shall be instituted.

(c) Personnel must constantly reexamine procedures and equipment to be sure safety has not been compromised by changes in test methods, overfamiliarity with the work, equipment deterioration, or stresses due to abnormal conditions.

(d) Trained supervision of all potentially hazardous activities involving liquid oxygen is essential. Everyone working with these materials must be taught both first aid and self aid. Personnel shall be instructed to call 911 (at Cleveland and at Plum Brook) for all emergency aid.

5.6.3 Protective Equipment

Protective clothing and equipment shall be included in personnel protective measures.

<u>Hand and foot protection</u>.—Gloves for work near cryogenic systems must be of good insulating quality. They should be designed for quick removal in case liquid oxygen gets inside. Because of the danger of a cryogenic splash, shoes should have high tops, and pant legs should be worn outside and over the shoe tops. Leather shoes are recommended.

<u>Head, face, and body protection</u>.—Personnel handling liquid oxygen shall wear splash protection. A face shield or a hood with a face shield shall be worn. If liquid oxygen is being handled in an open system, an apron of impermeable material should also be worn.

<u>Impermeable clothing</u>.—Oxygen will saturate clothing, rendering it extremely flammable. Clothing described as flame resistant or flame retardant in air may be flammable in an oxygen-enriched atmosphere. Impermeable clothing with good insulating properties is effective in protecting the wearer from burns due to cryogenic splashes or spills, but even these components can absorb oxygen.

<u>Oxygen vapors on clothing</u>: Any clothing that has been splashed or soaked with oxygen vapors shall be removed and shall not be used until it is completely free of the gas.

<u>Exposure to oxygen-rich atmospheres</u>: Personnel exposed to high-oxygen atmospheres should leave the area and avoid all sources of ignition for at least 20 minutes, until the oxygen in their clothing dissipates. Removal of clothing should be considered.

<u>Respiratory protection</u>.—Respiratory protection is not usually required in oxygen operations.

<u>Storage of protective equipment</u>.—Facilities should be available near the oxygen use or storage area for the proper storage, repair, and decontamination of protective clothing and equipment. Safety equipment shall be checked frequently to make sure it is operational.

5.6.4 Smoking Regulations

(a) Smoking and open flames are prohibited within a minimum of 50 feet of an oxygen system.

(b) Persons who have been in an oxygen-enriched environment shall not smoke until they have been in a safe area for at least 20 minutes. Clothing saturated with oxygen vapor is an extreme fire hazard.

5.6.5 Vapor Detection

High-oxygen-concentration detectors are not normally required.

5.7 EMERGENCY PROCEDURES

5.7.1 Emergency Action

The following priority actions shall be followed in case of an accident or emergency:

(a) Direct all personnel to evacuate the suspected hazardous area. Activate building evacuation alarms.

(b) Call the NASA Fire Department by dialing 911 at Cleveland or Plum Brook.

(c) Isolate or shut off all oxygen supply sources.

(d) Attempt to control the emergency with the installed facility system safety equipment and preplanned procedures.

5.7.2 Spills and Leaks

A general, facility-area fire hazard always exists when a major oxygen leak occurs. Nearby personnel, equipment, and buildings may ignite and burn in the oxygen-enriched atmosphere; however, proper system design, material selection, operating procedures, and adequate ventilation will minimize the danger.

Note that an oxygen vapor cloud may persist for a considerable distance downwind of a large liquid oxygen spill, because of lack of buoyancy of the cold gas.

5.7.3 Rescue

Only personnel trained in specific rescue techniques shall engage in rescue activities. All other personnel shall stay clear of an emergency area.

Rescue personnel must not try to pull a burning victim out of an oxygen-rich atmosphere since the rescuer risks catching fire also. Instead, deluge the victim with water and move him/her to fresh air as soon as possible.

Fire blankets must not be used to cover personnel whose clothing is saturated with oxygen. A blanket will prevent oxygen from dissipating from the clothing. Blankets also can become oxygen saturated, thus becoming a fire hazard.

5.7.4 Firefighting/Fire Control

Oxygen-enriched environments make all materials more ignitable, increase burning rates, and in general, decrease the time available for suppression. Experiments have shown that manual efforts to prevent ignition of adjacent materials, once burning has started, is very difficult.

Only personnel trained in specific firefighting techniques should be engaged in the fire fighting. All other personnel should stay clear of the area.

Procedures for controlling fires involving oxygen vary with the type and circumstances of the fire. The following general recommendations are to be used as a guide.

Electrical equipment.—Do not use carbon dioxide or dry chemicals on electrical fires. De-energize the electric power; then use water sprays for controlling the fire.

Liquid oxygen and fuel.—When the fire involves liquid oxygen and liquid fuels, control it as follows:

(a) If fuel and liquid oxygen are mixed but not burning, quickly evacuate personnel, isolate the area from sources of ignition, and allow the oxygen to evaporate. **Mixtures of fuel and liquid oxygen present an extreme explosion hazard.**

(b) Should a fuel-liquid oxygen fire occur, shut off fuel and oxygen supplies. Only water sprays or fog should be used to cool the fire. Foams should not be applied. The foam will retard oxygen evaporation and will not extinguish the fire.

5.7.5 Transportation Emergencies

Hazards caused by damage to oxygen transportation systems (road, rail, air, and water) include spills and leaks. Such spills may result in fires and explosions.

The first concern should be to prevent injury or death. In an accident or emergency, efforts should be made to move the oxygen transportation system to an open, safe location. All possible ignition sources should be removed and access restricted. If there has been major damage to the vacuum shell or vent system, pressure may build up, causing the liquid oxygen container to rupture explosively. Use water to extinguish secondary fires.

See Section 5.12.7 and appendix C for operational procedures.

5.7.6 Decontamination of Oxygen and Fuel Mixtures

Liquid oxygen will eventually evaporate from contaminated surfaces, given time and adequate ventilation.

When liquid oxygen has been contaminated by fuel, isolate the area from sources of ignition and quickly evacuate personnel. Allow the oxygen to evaporate and the residual fuel to reach ambient temperatures. Purge the oxygen system with gaseous nitrogen prior to any other cleanup step.

5.7.7 First Aid

Call the NASA Fire Department for emergency first aid by dialing 911 at Cleveland or Plum Brook.

Contact with liquid oxygen or its cold boiloff vapors can produce cryogenic burns (frostbite). Unprotected parts of the body should not be allowed to contact noninsulated pipes or vessels containing cryogenic fluids. The cold metal will cause the flesh to stick and tear.

Treatment of truly frozen tissue requires professional medical supervision since incorrect first aid practices almost always aggravate the injury. For reference, recommended emergency treatments for a cryogenic burn are outlined in appendix A; they shall be posted in oxygen handling areas.

5.8 OXYGEN STORAGE AND USE LOCATIONS

Suitable protection shall be provided between oxygen storage containers and incompatible materials, storage tanks, plant equipment, buildings, test areas, and property lines so that any accident or malfunction has a minimum effect on facility personnel and public safety. This protection may include separation by distance and by protective structures such as barricades or cell enclosures. The amount of separation required is based on the quantity of propellant present and the propellant use at the location. Planning for protection and safety of personnel and equipment must start at the initial facility design stages.

5.8.1 Policy

Oxygen used alone, as in pump, heat transfer, or component tests and bulk storage, can be stored safely without extensive separation distances from neighboring activities or structures as long as fuels are not present. The installation and location of such oxygen storage systems shall conform to the requirements in Sections 5.8.3 or 5.8.5 of this chapter.

When oxygen is used in conjunction with fuels, such as in combustion tests, rocket tests, or oxygen storage near fuel storage, additional requirements govern the storage and use locations. Quantity-distance requirements in Section 5.8.4 govern these situations, with specific distances required for different fuels, depending on the quantities of fuel and oxygen present.

The quantity-distance relations are intended as a basic guide in the choice of sites and separation distances. The distances given are based on the total quantity of propellants present. These distances may be impossible to achieve, but proper design can sometimes guarantee that only a portion of the total propellants will be involved in an accident. If Area Safety Committees are satisfied that such positive safeguards exist, lesser distances based on realistic propellant quantities may be used.

Area Safety Committees may also waive separation distance requirements where small quantities of liquid oxygen are used in well-controlled laboratory experiments. A hazard analysis shall be performed for each facility propellant system or subsystem. This hazard analysis shall serve as the basis for quantity-distance relationships.

Quantity-distance concept.—Quantity-distances are based on the concept that the effects of fire, explosion, and detonation can be reduced to tolerable levels if the source of hazard is kept far enough from people and facilities. These distances are based entirely on the estimated damage that could result from an incident, without considering probabilities or frequency of occurrence. Tests and experience are employed to determine how the effects of an accident are related to the quantity of material involved in the accident.

Quantity-distance tables.—The Armed Services Explosives Safety Board, in consultation with the Armed Services and NASA, has developed quantity-distance tables for liquid propellants. These are published as Department of Defense Manual 6055.9, "Ammunition and Explosives Safety Standards," and are included in Chapter 6 of this Manual (tables 6.3 to 6.5).

NOTE: These tables apply to liquid propellants only.

The Hydrogen Propellant Chapter of this Manual and NSS/FP–1740.11, NSS/FP–1740.12, and volumes 1 and 3 of CPIA–394 provide additional guidance and background information on quantity-distance relationships.

5.8.2 Site of Installations

To provide minimum risks to personnel and equipment, liquid oxygen installations shall be at recommended distances from buildings, fuel storage facilities, and piping. An impermeable, noncombustible barrier shall be provided to deflect any accidental flow of oxygen liquid or vapor from hazardous equipment such as pumps, hot electrical equipment, fuel lines, and so on. In addition, the following guidelines apply:

(a) Manholes and cable ducts are not safe for oxygen storage and test areas.

(b) Noncombustible barriers shall be provided to deflect any accidental flow of liquid oxygen away from the site boundaries and control areas.

(c) The release of spilled oxygen into public drainage systems must be prevented.

(d) Liquid oxygen tanks shall be located away from oil lines and places where hydrocarbons and fuels can accumulate.

(e) The location and amount of flammable liquid in nearby storage areas should be reviewed frequently.

(f) Ground slope modifications, appropriately sized gullies and dikes, and barricades should be used for protection.

(g) Oxygen storage and use facilities shall be protected from pump failures and other possible sources of shrapnel.

(h) Liquid oxygen systems shall not be located over or near asphalt roadways.

Barricades.—Shrapnel-proof barriers may be used to prevent the propagation of an explosion from one tank to another and to protect personnel and critical equipment. The proper height and length of a barricade shall be determined by line-of-sight considerations. Barricades, when required, must block the line-of-sight between any part of equipment from which fragments can originate and any part of the protected items. Protection of a public roadway shall assume a 12-foot high vehicle on the road.

Barricades are needed in oxygen test areas to shield personnel, dewars, and adjoining areas from blast waves or fragments and may also be needed to isolate liquid oxygen storage areas that are close to public property.

Dikes, shields, and impoundment areas.—To control travel of liquid and vapor due to spills, the facility should include dikes, shields for diverting spills, or impoundment areas. Any loading areas and terrain below transfer piping should be graded toward a sump or impoundment area.

Dikes surrounding liquid storage vessels shall be designed to contain 110-percent of the liquid oxygen in the fully loaded vessel.

5.8.3 Quantity-Distance Guidelines for Storing Bulk Liquid Oxygen Without Fuels

The recommended separation of bulk oxygen storage systems from inhabited buildings and public traffic routes is shown in table 5.2, of this chapter. Liquid oxygen, for bulk storage purposes, is considered a Group II propellant hazard with a Group A storage compatibility designation. The intragroup incompatible and compatible Group II storage distances are also included in table 5.2.

Primary quantity-distances.—The primary quantity-distances for bulk liquid oxygen storage shall be as established by DOD Manual 6055.9. These distances assume the main hazards are pressure rupture of the oxygen storage vessel and the resulting tank fragment shrapnel from a site.

Alternate quantity-distances.—An alternate quantity-distance may be used for bulk oxygen storage, contingent on Area Safety Committee approval. When all the stringent requirements of Chapter 3 of NFPA 50, "Standard for Bulk Oxygen Systems at Consumer Sites," and CGA Pamphlet S-1.3, "Pressure Relief Device Standards," are met, the Area Safety Committee may allow the NFPA 50 distances to apply.

Liquid oxygen cold-flow test operations without fuels.—Fire and fragment hazards govern this case if the system is closed. To qualify for this case, fuel and oxygen must never be employed concurrently, fuel and oxygen systems must be isolated so intermixing is impossible, and oxygen meeting MIL-P-25508 must be used.

Separation distances specified in Section 5.8.3 shall be used in this case as a minimum.

5.8.4 Liquid Oxygen in Static Test Stands and Incompatible Storage

When liquid oxygen storage and fuel systems are part of the static test stand or test area, there is a greater possibility of reaction with the fuel (propellant). A potential reaction is detonation of the oxygen-fuel mixture. For liquid oxygen in conjunction with a liquid fuel, the quantity-distances are based on blast hazards. These quantity-distance determinations are derived from DOD standards in DOD 6055.9.

<u>Determination of explosive equivalent</u>.—The equivalent amount of explosive is determined by multiplying the explosive equivalent factor times the total pounds of oxygen and fuel in a given location. See table 6.3 in Chapter 6.

<u>Quantity-distances for combinations of liquid oxygen and liquid fuel</u>.—Distances to inhabited buildings and public traffic routes for various quantities of equivalent propellant mixtures are given in Chapter 6, table 6.4.

Intraline distance is the minimum distance necessary to limit direct propagation of an explosion by the blast wave from one run or storage complex containing both oxidizers and fuels to another similar complex. Personnel injuries of a serious nature owing to fragments, debris, firebrands, and such are likely. Intraline distances are provided in Chapter 6, table 6.5.

5.8.5 Quantity-Distance Guidelines For Gaseous Oxygen Storage

Quantity-distances for bulk gaseous oxygen storage facilities are intended to provide facility protection from external fire exposure. The installation and location of bulk gaseous oxygen systems shall conform to the requirements in NFPA 50. Copies of NFPA 50 are available from the Safety Section of the Lewis Library.

As defined by NFPA 50, a bulk oxygen system is an assembly of equipment, such as oxygen storage containers, pressure regulators, safety devices, vaporizers, manifolds, and interconnecting piping, that has a storage capacity of more than 20,000 cubic feet (566 cubic meters) of oxygen, including unconnected reserves at the site, at normal temperature and pressure. The bulk oxygen system terminates at the point where oxygen at service pressure first enters the supply line. The oxygen containers may be stationary or movable.

Bulk oxygen storage systems shall be located either above ground and outdoors or shall be installed in a building of fire-resistant construction that is adequately vented and is used exclusively for storing oxygen. Containers and associated equipment should not be located beneath, or exposed to the failure of, electric power lines or piping containing any flammable liquid or gas.

Fire-resistant building construction is defined in NFPA 220, "Standard on Types of Building Construction."

5.8.6 Site and Equipment Design and Practice

<u>Structures</u>.—The storage facility (including support structures, roadways, drainage, etc.) should be made of fire-resistant materials and should be well ventilated. Normally,

because of their special insulation, liquid oxygen storage tanks are not covered. If a storage facility requires protection, any open shed structure of fire-resistant materials may be used.

Ventilation.—Areas in which liquid oxygen is handled must always be well ventilated to prevent excessive concentration of the gas. The liquid must never be disposed of in confined areas or in places that others may enter. Gaseous oxygen will increase the intensity of any fire.

Grounding and lightning protection.—Buildings, storage systems, and transfer facilities shall be properly grounded against static electricity and should have approved lightning protection.

Housekeeping.—Surrounding areas shall be kept free of grease, oil, oily waste, and all other organic materials (including vegetation). Smoking, sparks, and open flames are not permitted in storage areas.

Hazard warning.—The bulk oxygen storage location shall be permanently placarded "OXYGEN - NO SMOKING - NO OPEN FLAMES."

5.8.7 Electrical Wiring and Equipment

Oxygen storage and test installations are not classified as hazardous locations as defined and covered in article 500 of NFPA 70, "National Electric Code." Therefore, general purpose or weatherproof types of electrical wiring and equipment are acceptable, depending on whether the installation is indoors or outdoors. Such equipment shall be installed in accordance with the applicable provisions of NFPA 70.

Instrumentation and signal conditioner circuitry installed in oxygen propellant systems should be designed to minimize the overheating and arcing that might result from a sensor system short. Materials should be chosen to minimize the chance of ignition should a short occur. In situations where arcing can occur, testing should verify that the maximum possible spark energy is insufficient to cause ignition of adjacent materials (Bond et al. 1983).

5.9 MATERIALS

Safe use of oxygen requires the control of potential ignition energy mechanisms within oxygen systems by judiciously selecting ignition-resistant materials.

5.9.1 Factors Affecting Selection

The selection of a material for use with oxygen or oxygen-enriched atmospheres is primarily a matter of understanding the circumstances that cause oxygen to react with the material. Most materials in contact with oxygen will not ignite without a source of ignition energy. When an energy input exceeds the configuration-dependent threshold, ignition and combustion may occur.

To safely use oxygen, appropriate ignition-resistant materials specific to the oxygen environment must be selected. Only those oxygen compatible materials that have demonstrated combustion resistance well above the maximum expected operating conditions at each local area in a system should be chosen.

Currently, no single test has been developed that can be applied to all materials to determine either absolute ignition limits or consistent relative ratings.

5.9.2 Oxygen Compatible Materials

The following references, guidance, and information are provided for use by technical personnel in selecting materials compatible with oxygen service so that the probability of ignition and the risk of explosion or fire are minimized.

The basic reason for pursuing oxygen compatibility in systems is to minimize the fire hazard; it is wholly separate from considerations of corrosion, chemical attack, mechanical stability, material physical properties, and the ability to withstand cleaning procedures.

Much analytical and experimental work has been done in recent years to better understand the ignition-triggering mechanisms in the physical combustion of metallic and nonmetallic materials in pure oxygen environments (see ASTM Committee G4.05).

Major progress toward enabling oxygen systems to cope with the demands for higher performance, pressures, temperatures, and so forth has been made by designing systems that protect or shield the more susceptible nonmetallics from direct impingement or interface with oxygen (Bond et al. 1983), and by empirically testing materials in configurations representing their intended uses.

5.9.3 General Guidelines for Materials Selection

The final selection of a material for an oxygen application is an engineering tradeoff involving the chemical compatibility, the ignition and combustion characteristics, the physical properties of the material, the cost, and the consequences of a failure. Proper material choices, based on experimentally obtained data bases, can markedly reduce the probability of system ignition. Relative ranking and apparent ignition temperature values for many materials have been established through experimentation. See "Ignition" under Section 5.5.1, General Hazards.

Materials selected for cryogenic oxygen service shall have the required structural ductility and notch sensitivity characteristics.

The following references are strongly recommended:

"Design Guide for High Pressure Oxygen Systems" (Bond et al. 1983); the NASA Oxygen Safety Standard (NSS/FP–1740.12); and "Fire Hazards in Oxygen Systems" (ASTM G4.05). Copies are available from the Safety Section of the Lewis Library.

Other recommended references, which can be obtained through the Lewis Library, are "ASRDI Oxygen Technology Survey," Vol. 7 (Pelouch 1974) and Vol. 9 (Schmidt and Forney 1975); "Requirements for Materials and Processes" (JSC Specification SE–R–0006B, 1987); "Nonmetallic Materials Design Guidelines and Test Data Handbook" (JSC–02681, Rev. J, 1982); and "Ignition of Steel Alloys by Impact of Low-Velocity Iron/Inert Particles in Gaseous Oxygen" (Williams, Benz, and McIlroy 1988).

5.9.4 Metals for Low-Pressure Oxygen Service

Gaseous oxygen.—Metals acceptable for low-pressure (nominally less than 1000 psia) gaseous oxygen service include

- aluminum
- aluminum alloys
- copper
- copper alloys
- nickel
- nickel alloys
- stainless steel

Liquid oxygen.—Metals recommended for service with liquid oxygen are

(a) Nickel and nickel alloys

- Hastelloy B
- Inconel-X
- K-Monel
- nickel
- Rene 41

(b) Stainless steel types

- 304
- 304L
- 304ELC
- 310
- 316
- 321

(c) Copper and copper alloys

- copper
- Cupro-nickel

(d) Naval brass

(e) Admiralty brass

See table 5.3 for a partial list of these materials and their applications.

5.9.5 Prohibited Metals

Certain metals are prohibited from being used in oxygen systems (see JSC Specification SE–R–0006B).

Cadmium.—The toxicity and vapor pressure of cadmium restrict its use.

Titanium.—Titanium metal shall not be used with liquid oxygen at any pressure or with gaseous oxygen or air at oxygen partial pressures above 30 psia. Titanium and its alloys are impact sensitive in oxygen.

Magnesium.—Magnesium metal shall not be used in oxygen systems. In addition, its alloys shall not be used except in areas with minimal exposure to corrosive environments. Reactivity with halogenated compounds constrains its use with lubricants containing chlorine and fluorine.

Mercury.—Mercury shall not be used in oxygen systems in any form because it is toxic; in addition, it and its compounds can cause accelerated stress cracking of aluminum and titanium alloys.

Beryllium.—Beryllium and its oxides and salts are highly toxic and, therefore, they shall not be used in oxygen systems or near oxygen systems where they could be consumed in a fire.

5.9.6 Nonmetallic Materials

The primary concerns about using nonmetals in oxygen systems are their potential reactivity with the oxidant and the cryogenic temperatures encountered. Their ignition temperatures are generally lower than those for metals, and their low thermal conductivity and heat capacity make them much easier to ignite. The selection of these materials for use in oxygen is based on experience and testing of impact, ignition, and flammability characteristics. Consult ASRDI Oxygen Technology Survey, Volume 9 (Schmidt and Forney 1975) for more information.

Nonmetals that have been used successfully are

(a) Tetrafluoroethylene polymer (TFE, Halon TFE, Teflon, or equivalent)

(b) Unplasticized chlorotrifluoroethylene polymer (Kel F, Halon CTF, or equivalent)

(c) Fluoro-silicone rubbers and fluorocarbons (Viton type), batch-tested for acceptability

(d) Lubricants such as Krytox (DuPont) and Triolube 16 (Aerospace Lubricants)

Table 5.3 contains a partial list of nonmetals and their applications.

Nonmetallic material selection may be based on data presented in JSC Specification SE–R–0006B. Table 2 in "Design Guide for High Pressure Oxygen Systems" (Bond et al. 1983) lists ignition variability of nonmetallic materials currently used in oxygen systems and of nonmetallic materials not requiring batch testing control, along with some use restrictions.

5.9.7 Materials for High-Pressure Oxygen Service

The materials listed in table 5.3 of this chapter have demonstrated superior resistance to ignition and fire propagation in high pressure, nominally greater than 1000 psi, oxygen systems.

5.9.8 Selecting Material by Configuration Testing*

If it is not possible to find, even with batch/lot testing, materials that meet the functional requirements of a design, it may be possible to provide sufficient protection from ignition so that use of a susceptible material may be permitted. If this design approach is used, the adequacy of the design must be demonstrated through configuration testing at conditions more severe than the worst-case environment for the component in question. But configuration tests are considered valid only if they are conducted on hardware identical to the hardware proposed for use.

The configuration tests should use oxygen pressures at least 10 percent above the worst-case condition. Expected temperature limits should be exceeded by at least 50 °F. If the material is to be subjected to rapidly changing pressures, the pressure rise rate used in the configuration tests should be at least twice that which the component is expected to experience in operation.

If cycling or multiple reuse of the component is a design requirement, the configuration testing should exceed by a factor of four the expected number of cycles or reuses. Failure of the configuration test article before completion of the required number of cycles would limit the use life of the component to one-fourth the number of cycles actually completed before failure.

5.9.9 Materials Tests

If a designer chooses a material that has not been previously approved or evaluated for oxygen service, rationale, procedures, and data as presented in the following guides shall be provided to the Area Safety Committee for approval:

(a) ASTM G63–87 "Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service"

(b) ASTM G94–90 "Standard Guide for Evaluating Metals for Oxygen Service"

5.10 SYSTEM DESIGN

Safe use of oxygen requires the control of potential ignition energy mechanisms within oxygen systems by judiciously selecting system designs. The designer shall adhere to the principles listed in Section 5.2.2.

5.10.1 Safety Approval Policy

Before oxygen facilities, equipment, and systems are constructed, fabricated, and installed, the design safety shall be approved by either the Area Safety Committee or the Process Systems Safety Committee. The safety of systems for oxygen storage, handling, and use is enhanced when the facility plans, equipment designs, materials, and cleaning specifications are reviewed before construction begins.

*This information is taken from Bond et al. 1983.

5.10.2 Oxygen Design Supplements

Proven practical guidelines have been developed for the safe, successful design and use of oxygen propellant. The following publications are valuable supplements to this chapter. They are available in the Safety Section of the Lewis Library.

Mandatory.—The "Standard Guide for Designing Systems for Oxygen" (ASTM G88-90, 1991) is an essential part of oxygen system design principles. This standard is adopted as part of this chapter on oxygen safety. The designer/user is urged to obtain the latest revision of ASTM G88. The guide addresses system factors by which ignition and fire can be avoided.

Recommended.—The following are recommended guides:

(a) "Design Guide for High Pressure Oxygen Systems" (Bond et al. 1983) (This publication documents the critical and important detailed design data and provides a repository for such information, along with significant data on oxygen reactivity phenomena with metallic and nonmetallic materials in moderate to very high-pressure environments. The advanced user/designer should obtain a copy of this publication.)

(b) "ASRDI Oxygen Technology Survey," Volume 9 (Schmidt and Forney 1975)

(c) "Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping System" (CGA Pamphlet G4.4, 1980)

(d) "NASA Oxygen Safety Standard," Chapter 3 (NSS/FP-1740.12, to be published)

5.10.3 Component Design

The designer is cautioned that, in addition to the standard analyses relating to component or system function (stress, throughput, etc.), certain additional special analyses are recommended for the proper design of oxygen systems and must be considered in the design process. These analyses are listed by Bond et al. (1983) on page 4-1 of "Design Guide for High Pressure Oxygen Systems," which is available in the Safety Section of the Lewis Library.

5.10.4 General System Considerations

The designer shall perform those standard analyses related to system flow capacity, dynamic and static structural loads, thermally induced loads, heat transfer, and so forth. These routine analyses are not unique to high-pressure oxygen systems, but inadequate attention to them can result in system failures magnified by the extreme reactivity of oxygen.

The use of high-pressure oxygen requires certain design considerations that need special attention at the system level. The architecture, flow dynamics, thermal design, and cleanliness of the system are important. Differences between cryogenic-liquid, supercritical, and gaseous oxygen systems must be considered. Details are provided in Chapter 5 of "Design Guide for High Pressure Oxygen Systems" (Bond et al. 1983).

5.10.5 System Flow Velocity*

The primary source of concern under high velocity oxygen flow conditions is the entrainment of particulates and their subsequent impingement on a surface, such as at a pipe bend. The result can be propellant system ignition. The following flow dynamics design practices are recommended to avoid oxygen system fires:

(a) If practical, avoid velocities that are nominally above 100 feet/second in gaseous oxygen and avoid cavitation in liquid oxygen. Where this is impractical, use the alternate materials recommended in the references called out in Section 5.9 or those listed under the "High Pressure" column of table 5.3 of this chapter.

NOTE: During testing at NASA White Sands Test Facility (WSTF) in 1988, the oxygen velocities required for ignition of carbon steel, 316 stainless steel, and 304 stainless steel owing to the impact of a standard particle mixture were investigated at various oxygen pressures. Ignition of the particle mixture and the three alloys occurred at oxygen velocities greater than 146 feet/second and at pressures between 2900 and 3480 psi. The WSTF data suggest that specimen ignition appears independent of pressure up to about 4000 psi. Compared to these tests and other recent data, the CGA (CGA G-4.4) oxygen velocity limits for safe operations may be excessively conservative at high pressures and too liberal at low pressures. During 1991 communications with Joel Stoltzfus, WSTF, Joel stated that he considers flow velocities of 100 feet/second in gaseous oxygen systems to be low velocity flow. This value has been selected as the current guideline design value for this chapter. (See Williams, Benz, and McIlroy 1988 for details.)

(b) If possible, avoid the use of nonmetals at locations within a system where sonic flow or cavitation can occur.

(c) Maintain fluid system cleanliness and limit entrained particulates as specified in Section 5.11.

5.10.6 System Thermal Design

System thermal design considerations shall include thermal conditioning at startup, and avoiding the lockup of cryogenic oxygen in a system segment.

Startup thermal conditioning.—It is necessary to bring components to thermal equilibrium before starting up cryogenic oxygen turbopump systems and to avoid hazardous component thermal transients which may affect fits and clearances, cause rotor dynamic instabilities, or lead to high-speed rubbing friction. Any of these problems may result in ignition. Provision shall be made to provide thermal conditioning of the cryogenic system and components by gradually bleeding through cryogenic gas, then liquid.

Lockup of cryogenic oxygen in system segments.—Cryogenic oxygen hydraulically locked up between two valves or flow control components can absorb heat and, through the increase of pressure, cause structural failure. The system and components shall be designed to provide appropriate pressure relief.

*From Bond et al. 1983; Schmidt and Forney 1975; and Williams, Benz, and McIlroy 1988.

5.10.7 Design for System Cleanliness

Designing for cleanliness is extremely important in oxygen systems (refer to Sec. 5.11) Metallic and nonmetallic contaminants and nonvolatile residues may have been left in components and systems after fabrication and assembly. Filters may need to be located throughout a system to control particulate contamination. And appropriate system flush and purge ports should be designed into the system. These ports should be located at appropriate high and low points to allow effective flush or purge of the system.

5.10.8 System Electrical/Electronic Design

Section 5.8.7 of this chapter addresses system electrical design.

5.11 SYSTEM CLEANLINESS

Safe use of oxygen requires the control of potential ignition energy mechanisms within oxygen systems by maintaining scrupulously clean systems.

Cleanliness (contamination control) is critical in oxygen components and systems. Contamination can cause ignition of components or systems by a variety of mechanisms, such as particle impact, mechanical or pneumatic impact, or spontaneous ignition. In an oxygen environment, contaminants increase the ignitability of both metallic and non-metallic materials.

5.11.1 General Policy

Before being placed in service, liquid and gaseous oxygen systems and their system components shall be completely cleaned to meet Lewis end-result-cleanliness quality specifications (Sec. 5.11.4).

Furthermore, since oxygen components and systems shall be periodically reinspected to ensure that safety and component integrity are maintained during the life of the system, there are more opportunities for contamination. If the oxygen system contains components with a history of in-service failures, appropriate traps or other easily analyzed components shall be removed, inspected, and periodically replaced (Sec. 5.11.5).

5.11.2 Oxygen Cleanliness Supplements

The following publications, available from the Safety Section of the Lewis Library, contain proven, practical guidelines that were developed to safely and successfully control contamination in oxygen propellant systems.

Mandatory.—ASTM G93-88, "Standard Practice for Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments," is an essential part of this oxygen system cleanliness directive.

Recommended.—The following are highly recommended sources of information for oxygen system cleanliness:

(a) CGA Pamphlet G-4.1, "Cleaning Equipment for Oxygen Service"

(b) NASA Reference Publication 1113, "Design Guide for High Pressure Oxygen Systems," (Bond et al. 1983), Chapters 6 to 8

(c) ASRDI Oxygen Technology Survey, Volume 2, "Cleaning Requirements, Procedures, and Verification Techniques" (Bankaitis and Schueller 1972)

(d) MSFC-Spec-164A (1970), "Cleanliness of Components for Use in Oxygen, Fuel, and Pneumatic Systems" (contains acceptable methods of cleaning pipe, tubing, and flexhose)

(e) KSC-C-123F, 1984, "Specifications for Surface Cleanliness of Fluid Systems"

5.11.3 Cleaning Procedures

Cleaning methods and subsequent inspections must produce the degree of cleanliness required for the safe operation of oxygen service equipment and the necessary propellant purity required for experimental test operations.

Cleaning a component or system for oxygen service involves the removal of combustible contaminants, including the surface residue from manufacturing, hot work, and assembly operations, as well as the removal of all cleaning agents. These cleaning agents and contaminants include solvents, acids, alkalies, water, moisture, corrosion products, non-compatible thread lubricants, filings, dirt, scale, slag, weld splatter, organic material (such as oil, grease, crayon, and paint), lint, and other foreign materials.

Injurious contaminants can be removed by cleaning all parts and maintaining this condition during construction; by completely cleaning the system after construction; or by a combination of the two.

The prevention of recontamination before final assembly, installation, and use is essential to safe oxygen system operation.

Responsibility.—The organization performing the cleaning service shall have the responsibility of developing detailed cleaning procedures. The Lewis oxygen systems cleanliness acceptability shall be based only on the quality specifications of the cleaning end result and **not** on the cleaning procedures used. The organization performing the cleaning shall be completely responsible for meeting the cleanliness specifications of Section 5.11.4, regardless of the procedures used.

The Lewis organization responsible for operating the oxygen system or equipment must be assured that the procedures are compatible with the units being cleaned and that the procedures will accomplish the appropriate level of cleanliness.

The Lewis system owner/user has the option of exercising approval authority on the cleaning procedures to be used on his/her systems.

Cleaning procedure safety.—The organization performing the cleaning services shall have responsibility for all safety aspects of oxygen cleaning procedures. Guidance for safe procedures can be found in ASTM G-93-88, Section 8, "Cleaning Methods."

Special considerations.—Complete systems may require disassembly for suitable cleaning. Components that could be damaged during cleaning should be removed and cleaned separately. Cleaning or disassembly operations that might affect tolerances or impair calibration of precision components should be performed only under the supervision of personnel qualified in the handling, calibration, and assembly of the components.

The cleaning procedures established for each system or component shall be compatible with the design configurations. Prior to use, establish the compatibility of cleaning agents with all construction materials, making sure that time or temperature constraints are not exceeded.

5.11.4 Verification of Oxygen System Cleanliness

A key element of the Lewis contaminant control safety plan is the final inspection and verification of system cleanliness by using an approved Lewis acceptance specification. Experience has shown that approximately one-half of all parts cleaned fail on the initial sampling to meet either the particulate or the nonvolatile residue (NVR) specification. Should this occur, recleaning is required until all parts pass both specifications (see Bond et al. 1983).

Inspection procedures.—Procedures detailed in ASTM G–93–88, Section 10, "Inspection," shall be followed to verify cleanliness of components and systems for Lewis oxygen service.

Lewis cleanliness acceptance criteria.—Acceptance criteria for all systems and components are based on KSC–C–123F, "Surface Cleanliness of Fluid Systems." The acceptance level shall be 300 Å. This represents a particle limit and a hydrocarbon limit identical to those which Kennedy Space Center uses on ground equipment in oxygen service.

NASA has no standardized procedures for cleaning components or systems. Cleaning organizations may employ varying methods to meet the acceptance criteria of KSC–C–123F and the Lewis Oxygen System Cleanliness Specification.

Lewis Oxygen System Cleanliness Specification.—Appendix B of this chapter contains a written cleanliness specification based on KSC–C–123F, which is suitable for ground-based gaseous and liquid oxygen propellant systems at Lewis. The specification covers both oxygen propellant systems and transducers.

5.11.5 Recommendations for Reinspection

Oxygen components and systems shall be reinspected periodically to ensure that safety and component integrity are maintained during the life of the system. Determination of system and component reinspection intervals has proven to be a complex task. Detailed knowledge of construction materials, pressure levels, the use environment, and the service the system is performing must be applied. A record of reinspections must be kept on file and labels placed on the inspected components. In establishing the reinspection intervals, the following items should be considered:

(a) Routine disassembly and reassembly of piping systems invariably increases the level of system contamination because particulates are generated.

(b) Sampling of an assembled system for gas-borne contaminants yields only limited data on the internal cleanliness. This method of system sampling cannot be directly correlated with the cleanliness of internal system surfaces.

(c) The reinspection plan must address the design service life of components.

(d) Additional insight regarding system contamination levels can be gained through systematic inspection of components (e.g., transducers, flexhoses, relief valves, filters) removed for calibration, proof-testing, or periodic maintenance.

(e) Cleanliness levels in components and systems that have been in service shall be reverified to make sure the requirements of the Lewis Oxygen System Cleanliness Specification under Section 5.11.4 of this chapter are met.

(f) Reassembly procedures shall adhere to guidelines for original assembly, including assembly checkout.

Assembly of propellant systems.—After system and component disassembly and cleaning, reassembly of components and systems must be stringently controlled to ensure that the achieved cleanliness levels are not compromised.

All components requiring reassembly (e.g., valves, regulators, and filters) should be reassembled in a filtered-air environment such as a clean room or flow bench. Personnel should be properly attired in clean-room garments and gloves. All tools that contact component internal parts must be cleaned to the specified levels of the parts.

Final system checkout.—After the system has been reassembled, a final pressure integrity and leak test should be performed with an appropriately filtered inert gas that has been analyzed for contaminants.

Cryogenic cold-shock: Cold-shocking a newly assembled liquid oxygen system by loading it with clean liquid nitrogen following final assembly is highly recommended. After the cryogenic cold-shock, the system should be emptied of liquid nitrogen and warmed to ambient temperature. Bolts and threaded connections must then be retorqued to prescribed values, and gas leak-checking procedures should follow.

The entire system should be inspected for evidence of cracking, distortion, or any other anomaly, with special attention directed to welds. Then system cleanliness must be checked and verified.

Final operational tests: Final operational tests should be run with oxygen (liquid or gas, as required by the system) at rated pressure. If it is possible to substitute nitrogen for this test, this should be done for greater safety in the operational test. Only verified clean, dry nitrogen shall be used for these tests. It is prudent to recheck the system filters for cleanliness after the test is completed.

It is also a good practice to perform the first oxygen pressurization of a system by remote control, since assembly-generated contaminants can cause ignition.

Hydrostatic tests: **Do not** perform hydrostatic tests on cleaned systems since this is likely to contaminate them. Conduct these tests on the components before cleaning and final assembly.

5.12 OPERATING PROCEDURES AND POLICIES FOR OXYGEN PROPELLANT SYSTEMS

Safe use of oxygen requires the control of potential ignition energy mechanisms within oxygen systems by using appropriate operational procedures.

5.12.1 Formal Procedures

All oxygen operations shall be conducted by knowledgeable and trained personnel using formal written procedures. Personnel involved in design and operations shall carefully adhere to the safety standards of this chapter and must comply with regulatory codes.

Standard operating procedures (SOP's) with checklists shall be developed for common operations. The SOP's shall be prepared by persons familiar with the work being done and shall be reviewed and implemented by line management. SOP's for all hazardous operations shall be approved by the Area Safety Committee.

The procedures, which should be reviewed periodically (at least quarterly) for observance and improvement, shall provide for the control of hazards to a level of acceptable risk. Special procedures shall be developed to counter hazardous conditions, when the system design and the use of safety equipment do not reduce the magnitude of a potential hazard to acceptable levels. The effectiveness of these procedures shall be verified through demonstration tests using sound engineering principles and judgement.

The buddy system, as specified in Section 5.6.1, shall be followed for oxygen use operations.

5.12.2 Operator Certification

Operators shall be certified as "qualified" for handling liquid and gaseous oxygen and "qualified" in the emergency procedures for handling leaks and spills. These operators must be kept informed of any changes in facility operations and safety procedures.

Administrative procedures for certification of a qualified operator are provided in Chapter 2 of the Lewis Safety Manual. Before being certified to work with liquid or gaseous oxygen, the operator should demonstrate

(a) Knowledge of the nature and properties of oxygen in both the liquid and gaseous phases

(b) Knowledge of approved materials that are compatible with liquid and gaseous oxygen under operating conditions

(c) Knowledge of proper equipment and proficiency in its operation

(d) Familiarity with manufacturers' manuals detailing equipment operations

(e) Proficiency in the use and care of protective equipment and clothing, and safety equipment

(f) Proficiency in self aid, first aid, and proper emergency actions

(g) Proficiency in maintaining a clean system and clean equipment in oxygen service

(h) Recognition of normal operations and of symptoms that indicate deviations from such operations

(i) Conscientiousness in following instructions and checklist requirements

5.12.3 Test Cell Entry

Entry into an operating test cell must be considered dangerous. Authorized personnel may gain entry **only** after conditions within the cell have been determined to be safe.

Test cells and buildings containing combustible or explosive mixtures shall not be entered under any condition. Personnel should be warned of combustible or explosive mixtures and high or low oxygen concentrations by detectors, sensors, and continuous sampling devices that operate both audible and visible alarms.

5.12.4 Transfer and Flow Guidelines

These general guidelines apply to both gaseous and liquid oxygen operations.

(a) Storage, transfer, and test areas should be kept neat and free from combustibles and should be inspected frequently. An adequate water supply should be available for fire fighting.

(b) The manner in which transfer equipment is operated will be determined by local designs and construction, the type of equipment selected, and the procedures prescribed by either the cognizant authority or the equipment manufacturer.

(c) Transfer and flow operations shall include procedures to assure that an appropriate level of oxygen system cleanliness has been reached before oxygen flow is begun.

(d) After extended use and after periods of extended shutdown, inspections must be made for possible oxygen system contamination and for evidence of unsafe conditions in the equipment.

(e) Great care must be exercised when reusing oxygen that has flowed through a propellant system. Flowing oxygen back to the supply tank may contaminate the supply; dumping or venting once-used oxygen is a preferred procedure.

5.12.5 Oxygen System Maintenance or Repair

Provisions shall be made to keep an oxygen system clean when it is opened for maintenance or repair. The following steps must be taken:

(a) Isolate, insofar as possible, the portion of the system to be entered.

(b) Verify that the system is drained and depressurized. Purge the oxygen system with an inert gas before opening it up.

(c) Confirm that the entire system is at ambient temperature to keep contaminated air from being sucked into the system. This is particularly important if a part of the system is nitrogen jacketed. "Breathing" may also be caused by barometric pressure variations or temperature changes. A slight positive pressure or purge may be necessary to keep the system from "breathing."

(d) Cap or seal openings into the part prior to reinstalling it in the system.

(e) Purge and reclean repaired parts of the system prior to reinstallation.

Provisions should be made for periodic cleaning of possible contaminant traps in a system, but every effort should be made to avoid such traps in the design.

When working on equipment where oxygen enrichment is a possibility, isolate the equipment by inserting a blank. A shutoff valve is not considered a positive means of isolation from a working oxygen system.

5.12.6 Operational Procedures For Gaseous Oxygen Tube Trailers and Cylinders

Quick-acting valves must not be used to start or stop gaseous oxygen systems. Most failures in gaseous oxygen systems are caused by sudden flow changes.

<u>Specific requirements for gaseous oxygen tube trailers.</u>—All Lewis-owned gaseous oxygen tube trailers shall be fitted with remotely operated transfer shutoff valves of a Lewis standardized design and configuration. Only inert gas or air shall be used to operate these remote shutoff valves. Oxygen gas from the trailer sample panel shall **NEVER** be used to operate valves.

Trailer-to-facility transfer lines may be made of corrugated stainless steel or Teflon hose, with the proper pressure rating, inside an external braid of stainless steel. In such cases, proper restraining cables and anchoring are required. Alternatively, stainless steel tubing with the proper pressure rating may be used. Forming the tubing into a large loop provides for some flexibility in the connection.

Gaseous oxygen flow velocities in the transfer line should be kept below 100 feet/second unless higher velocities can be shown to be safely tolerated.

Appendix C contains specific operational procedures to connect, leak-check, purge, start up, and shut down the Lewis gaseous oxygen tube trailer systems.

Operational procedures for portable gaseous oxygen cylinders.—Specific operational procedures for the safe use of gaseous oxygen cylinders are found in the Compressed Gas Association Pamphlet CGA G-4, Sections 4 and 5. This publication is adopted as an essential part of this chapter. Adherence to these procedures is mandatory.

5.12.7 Operational Procedures for Liquid Oxygen Systems

Specific operational check sheets shall be formulated and approved by the Area Safety Committees. They shall encompass the following elements in the general operating procedure.

Leak-check systems.—Before operating a liquid oxygen system, cold-shock the entire system with clean liquid nitrogen and then check for leaks. Before loading, purge the system of air and water vapor. Recheck for cleanliness to be sure that cold-shocking and leak-checking did not contaminate the system.

Loading.—Fill the system with liquid oxygen **gradually** to limit "geysering," severe local temperature gradients, and surges in the system.

Operation.—Do not proceed with testing until the system has reached thermal equilibrium. This precaution is particularly pertinent to turbomachinery components in the system.

Shutdown.—Purge the oxygen reside from all components of the system.

Unloading and transfer leaks.—Make sure transfer hoses have been disconnected before moving the loading vehicle. Leaks are usually caused by deformed seals or gaskets, valve misalignment, or failures of flanges and equipment. A liquid oxygen leak may cause further failures of construction materials.

System leak repair.—Do not repair any leak until all pressure in the system has been bled. All tools and fittings should be cleaned appropriately before use. If welding or brazing is required, the system must be made inert, repaired, and recleaned.

Condensation of contaminants during loading.—Improper loading procedures for cryogenic oxygen can result in condensation of water or any other condensable vapor inside the system. In large systems, even contaminant levels measured in parts per million can produce a sizable frozen mass that could impede flow or system function.

Before loading a cryogenic system, purge or evacuate from the system all air, water, and condensable vapors. Experimentation may be required to define the degree of purge or the number of evacuation cycles required.

Sampling techniques—When required, collect samples of oxygen in a sealed container of appropriate design. Follow cleanliness and purging procedures to avoid contamination of the sample.

5.12.8 Transportation of Oxygen

Oxygen, compressed oxygen, and refrigerated liquid oxygen are subject to the U.S. Department of Transportation regulations for hazardous materials. For complete information and specifications, refer to Title 49, Code of Federal Regulations, Subch. C: "Hazardous Materials Regulations."

5.12.9 Disposal of Oxygen

As classified in Title 40, Code of Federal Regulations, Parts 260 to 265, "Protection of the Environment," oxygen is not considered a hazardous waste. Uncontaminated liquid oxygen is best disposed of by allowing it to vaporize from a normal heat leak into the container and letting the vapor escape through the vent. Liquid oxygen may also be piped into an area free from combustible material and allowed to vaporize.

5.13 ADOPTED REGULATIONS

This chapter is based on the best information available in 1991. Much of the material was compiled directly from Bond et al. (1983); Bankaitis and Schueller (1972); Schmidt and Forney (1975); NSS/FP–1740.12; ASTM G93–88; CGA Pamphlets G4.1 and S–1.2; NFPA 50 and 53M; and volumes 1 and 3 of CPIA–394; as well as the oxygen chapter of the 1973 Lewis Operational Safety Manual. Experience with oxygen systems gained over the past 30 years at Lewis heavily influenced the development of the new safety chapter.

This chapter was compiled by Wayne A. Thomas, Lewis aerospace engineer. It represents the consensus of a 12-member Technical Contributing and Review Committee of Lewis engineers and technicians (see appendix D), who are considered experts on oxygen safety, design, fabrication, and use. Grateful acknowledgment is given for their support in providing technical monitoring of this standard, for the constructive reviews provided by other experienced members of the Lewis staff, and for the support of technical writer Wilma Graham.

The following documents or portions thereof are referenced within this chapter as mandated regulations and shall be considered as part of the requirements of this chapter; however, if there is a conflict between information presented in a reference and information contained in this chapter, the chapter information shall govern. Copies of these documents may be obtained from the Safety Section of the Lewis Library.

ASTM G88-90, "Standard Guide for Designing Systems for Oxygen Service"

ASTM G93-88, "Standard Practice for Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments"

CGA Pamphlet G–4, "Oxygen"

A special significant reference is the "NASA Oxygen Safety Standard," NSS/FP-1740.12 (to be published). It provides a good source of additional practical safety, design, and handling information on the use of oxygen in gas and liquid forms. Mr. Paul Ordin (deceased), along with a large group of other contributors, compiled this extensive collection of oxygen information. Many useful references are also provided.

TABLE 5.1—SELECTED SAFETY-RELEVANT PHYSICAL PROPERTIES OF GASEOUS AND LIQUID OXYGEN

[From Roder and Weber 1972; CGA Pamphlet G–4, 1987; and CRC Handbook of Chemistry and Physics.]

Reference temperature, °F [°R] (K)	68 [527.7] (293.15)
Standard pressure (1 atm), psia (kPa abs)	14.69 (101.325)
Density,[a] lb/ft^3 (kg/m^3)	0.0831 (1.33)
Specific volume,[a] ft^3/lb (m^3/kg)	12.03 (0.751)
Specific heat,[a] C_p, Btu/lb-°R (J/g-K)	0.220 (0.919)
C_v, Btu/lb-°R (J/g-K)	0.157 (0.68)
Velocity of sound,[a] ft/sec (m/sec)	1070 (326)
Critical density, lb/ft^3 (kg/m^3)	27.2 (436.1)
Critical pressure, psia (kPa abs)	731.4 (5043)
Critical temperature, °F [°R] (K)	–181.43 [278.3] (154.6)
Vapor pressure at selected temperatures, psia (kPa)	
268.6 °R	588 (4052.0)
259	441 (3039.0)
240	294 (2026.5)
216	147 (1013.2)
196	73.5 (506.60)
175	29.4 (202.64)
162	14.7 (101.32)
Boiling point at 1 atm, °F [°R] (K)	–297.3 [162.4] (90.18)
Density,[b] lb/ft^3 (kg/m^3)	71.23 (1141)
Specific heat,[b] C_p, Btu/lb-°R (J/g-K)	0.405 (1.69)
C_v, Btu/lb-°R (J/g-K)	0.221 (0.93)
Velocity of sound,[b] ft/sec (m/sec)	2963 (903)
Heat of vaporization,[b] Btu/lb (J/g)	91.59 (213)
Heat of fusion at triple point, Btu/lb (J/g)	5.98 (13.9)
Triple point temperature, °F [°R] (K)	–361.8 [97.9] (54.35)
Triple point pressure, psia (kPa)	0.022 (0.152)

[a]At reference temperature and standard pressure (527.7 °R and 1 atm).
[b]At 162.4 °R and 1 atm.

TABLE 5.2—SEPARATION DISTANCES[a] FOR BULK LIQUID OXYGEN STORAGE

[These distances apply to liquid oxygen only and assume the main hazards are pressure rupture of the oxygen storage dewar and the resulting tank fragment shrapnel from the storage site. Data are from DOD 6055.9 and from CPIA-394-VOL3, table D-2.2.]

Total amount of liquid oxygen stored, lb		Distance[a] from inhabited buildings, highways, and incompatible group II storage, ft	Distance to another LOX storage and other compatible group II storage, ft
Over	Not over		
0	100	60	30
100	200	75	35
200	300	85	40
300	400	90	45
400	500	100	50
500	600	100	50
600	700	105	55
700	800	110	55
800	900	115	60
900	1 000	120	60
1 000	2 000	130	65
2 000	4 000	150	75
4 000	6 000	165	80
6 000	8 000	175	85
8 000	10 000	180	90
10 000	20 000	205	100
20 000	30 000	220	110
30 000	40 000	230	115
40 000	50 000	240	120
50 000	60 000	250	125
60 000	70 000	255	130
70 000	80 000	260	130
80 000	90 000	265	135
90 000	100 000	270	135
100 000	150 000	295	145
150 000	200 000	310	155
200 000	300 000	330	165
300 000	400 000	350	175
400 000	500 000	360	180
500 000	600 000	375	185
600 000	700 000	385	190
700 000	800 000	395	195
800 000	900 000	405	200
900 000	1 000 000	410	205

[a]This distance was arbitrarily selected as three-fourths the group-III inhabited building distance and is considered reasonable because of the lesser hazard.

TABLE 5.3—SOME RECOMMENDED MATERIALS FOR OXYGEN SERVICE[a]

[From Bond et al., 1983.]

Application	Low pressure[b]	High pressure[c]
Component bodies	Nickel alloy steel Stainless steel	Monel Inconel 718
Tubing and fittings	Copper Stainless steel Steel Aluminum Aluminum alloys	Monel Inconel 718
Internal parts	Stainless steel	Monel Inconel 718 Beryllium copper
Springs	Stainless steel	Beryllium copper Elgiloy Monel
Valve seats	Stainless steel Monel Inconel	Gold or silver plated over Monel or Inconel 718
Valve balls	Stainless steel Tungsten carbide	Sapphire
Lubricants	Everlube 812 Microseal 100-1 and 200-1 Triolube 1175 Krytox 240AB and 240AC Braycote 3L-38RP	Batch/lot-tested Braycote 3L-38RP Batch/lot-tested Everlube 812 Krytox 240AC
O-seals and backup	TFE, Halon TFE Teflon Kel F Viton	Batch/lot-tested Viton Batch/lot-tested Teflon
Pressure vessels	Nickel steel Stainless steel Steel Aluminum alloys	Inconel 718

[a]This table lists materials for conservative design standards. Materials listed in the "Low pressure" column and other materials that are not listed may be suitable for more extreme environment oxygen service. Careful engineering analysis and rationale shall be used to select alternate materials.

[b]Nominally less than 1000 psi.

[c]Nominally greater than 1000 psi.

5.14 APPENDIX A—FIRST AID FOR CONTACT WITH CRYOGENIC MATERIAL

(To be posted at test site)

Contact with liquid oxygen or its cold boiloff vapors can produce cryogenic burns (frostbite). Unprotected parts of the body should not be allowed to contact uninsulated pipes or vessels containing cryogenic fluids. The cold metal will cause the flesh to stick and tear. Treatment of frozen tissue requires medical supervision since incorrect first aid practices always aggravate the injury.

5.14.1 Exposure to Cryogenic Gases/Liquids

Cryogenic burns result when tissue comes into contact with cold gases, liquids, or their containers. Contact may result in skin chilling or true tissue freezing. Commonly, only small areas are involved, with injury to the outer layers of the skin.

Small quantities of cryogenic material may evaporate from the skin before actual freezing occurs. Such an injury typically produces a red area on the skin. More significant injury is caused by true freezing: the formation of crystals within and around the tissue cells. Frozen tissue always assumes a yellowish-white color, which persists until thawing occurs.

5.14.2 Treatment of Frozen Body Tissue

Treatment of frozen tissue requires medical supervision since incorrect first aid practices always aggravate the injury. In an emergency the treatment of choice is to rewarm the affected part by immersing it in a water bath at a temperature between 100 and 112 °F (312 and 317 K). Temperatures outside the indicated range can aggravate the injury. This warming should be continued until the involved area becomes flushed. If the frozen area has already thawed, rewarming is not necessary.

Long-term treatment techniques, such as the type of dressing and medications, are medical considerations outside the scope of this Manual. In general, cryogenic injuries are treated like thermal burns with appropriate care to prevent infection, to which the injured tissue is very prone.

In the field it is safest to do nothing other than cover the involved area, if possible, and transport the injured person to a medical facility.

Safety showers may be provided. However, they are exclusively for nonmedical purposes such as fire extinguishing or flushing acid. Safety showers should be tagged, "Not to be used for treatment of cryogenic burns."

NOTE: Attempts to administer first aid when body tissue is frozen will often be harmful. Here are some important DON'Ts:

(a) Don't remove frozen gloves, shoes, or clothing, except in a slow, careful manner (skin may be pulled off inadvertently). Unremoved clothing can easily be put into the warm water bath.

(b) Don't massage the affected part.

(c) Don't expose the affected part to temperatures higher than 112 °F (e.g., a heater or a fire). This superimposes a burn and gravely damages already injured tissues.

(d) Don't expose the affected part to temperatures lower than 100 °F.

(e) Don't apply snow or ice.

(f) Don't use safety showers, eyewash fountains, or other sources of water since the temperature will almost certainly be incorrect therapeutically and will aggravate the injury.

(g) Don't apply ointments.

5.15 APPENDIX B—CLEANLINESS SPECIFICATION FOR GASEOUS/LIQUID OXYGEN SERVICE IN LEWIS TEST FACILITY SYSTEMS

5.15.1 Scope

This specification establishes the minimum requirements for system and component cleanliness for Lewis test facility gaseous and liquid oxygen service. It reflects the requirements of KSC-C-123F, 1984; MSFC-HDBK-527, Rev. F; JSC SN-C-0005, Rev. A; and MSFC-Spec-164A. It includes the acceptable minimum cleanliness, cleaning, packaging, and verification requirements.

Rigid procedures shall be followed in preparing, assembling, testing, and packaging components to assure cleanliness and to avoid the inherent danger of oxygen reacting with grease, oil, or other foreign matter. Any procedure not complying with this specification must be submitted to the Assurance Engineering Office and/or the Area Safety Committee for approval.

This specification does not preclude the supplier's responsibility for providing a product that meets the system performance requirements and acceptability for oxygen use. It shall be considered an integral part of the purchase agreement between the vendor and NASA Lewis.

5.15.2 Requirements

Materials.—All materials used shall have been previously determined to be compatible with oxygen and should be widely accepted throughout the aerospace industry. All materials shall be approved by the Lewis Assurance Engineering Office and/or the Area Safety Committee.

Lubricants.—Liquid oxygen is a powerful oxidizing agent, so a petroleum-based lubricant must not be used. Special lubricants such as the fluorolubes or the perfluorocarbons, which have been tested and found suitable for oxygen service, may be used. All lubricants shall be approved by the Lewis Assurance Engineering Office and/or the Area Safety Committee.

Cleanliness.—All component parts shall be free of burrs, chips, scale, slag, or foreign matter and shall be cleaned prior to assembly. Inspection for cleanliness shall consist of the following.

Visual inspection: Visible contamination shall require recleaning of the surface. Discoloration due to welding will be permitted, providing no scale or rust is associated with the discoloration. Visual inspection aided by an ultraviolet light source (3200 to 3800 angstrom wavelength) shall show no evidence of fluorescence from contamination.

White cloth inspection: Surfaces shall be rubbed in two directions with a clean, lint-free white cloth. Any evidence of oil, rust, stain, scale, or foreign matter will be cause for rejection. The cloth may be examined under natural or ultraviolet light. Use of ultraviolet light (3200 to 3800 angstrom wavelength) shall show no evidence of fluorescence from contamination.

Solvent rinse: A filtered nonvolatile residue of 5 milligrams/liter trichlorotrifluoroethane (Freon) or trichloroethane (tric) shall be used as a cleaning solvent. Sufficient quantities of solvent rinse shall be used so as to yield 100 milliliters/square foot of internal surface area. The solvent rinse shall be performed by either sloshing or agitating the fluid around the inside surface of the components and straining it through a 5-micron, or finer, filter.

CONTAMINATION LIMITS

(a) Solid Particles

Particle size, μm	Maximum number per 100-ml sample (millipore test)
<100	Unlimited
100 to 250	93
251 to 300	3
>300	0

(b) Fibers

Fiber[a] length, μm	Maximum number per 100-ml sample (millipore test)
0 to 500	20
501 to 1000	3
1001 to 1875	1
>1875	None

(c) Nonvolatile residue

Maximum residue, mg/ft^2
1.0

(d) Hydrocarbon limit

Method	Result
Ultraviolet light	No fluorescence
Infrared spectrophotometer	5 ppm hydrocarbon

(e) Total solids and fibers

25 mg/ft^2 (maximum)

[a]Up to 25 μm diameter.

Assembly.—The component parts shall be individually cleaned prior to assembly. Precautions shall be used during handling and assembly to preclude contamination of component parts. Final assembly and inspection shall be done in a laminar-airflow clean work area whenever possible.

Cleaning.—Cleaning shall consist of the typical cleaning, rinsing, and drying procedures used throughout the aerospace industry:

(a) Cleaning shall consist of a thorough flushing of all surfaces with aqueous detergent solutions.

(b) Rinsing shall consist of a thorough rinsing and flushing with de-mineralized water, followed by rinsing and flushing with isopropyl alcohol.

(c) Drying shall consist of blowing dry with filtered gaseous nitrogen or oil-free air.

Inspection.—Inspection of assembled cleaned components shall be performed by the solvent rinse method where possible. (This is generally done during the final cleaning stages and just prior to the drying operation.) Filtered Freon or tric solvent shall be used at a rate of 100 milliliters per square foot of internal wetted surface area. (For all components having less than one square foot of internal wetted surface area, use 100 ml of solvent.) The solvent rinse shall be performed by either sloshing or agitating the fluid around the inside surface of the component to ensure dislodgment of particles. The rinse shall be poured through a filter sized to detect all particles greater than 100 microns. The assembled component, or any part thereof, shall be recleaned if it fails to pass the inspection(s).

The Lewis Assurance Engineering Office and/or Area Safety Committee reserves the right to inspect the finished component for cleanliness.

Packaging.—On finished components, seal all openings with appropriate blind flanges, plugs, or caps, or securely tape polyethylene sheeting (at least 0.008-inch thick (0.20 millimeters)) to prevent contamination, making sure the tape does not touch any cleaned surface. Components shall then be double packed and sealed with polyethylene (0.006-inch thick minimum (0.15 millimeters)) before they are put into a shipping container. Pad sharp edges before packaging to preclude puncturing the package. Exercise care in packaging to prevent shredded or abraded polyethylene material from becoming a contaminant.

Verification.—Finished components shall be affixed with a tag, label, or stamp showing that they meet the requirements specified herein for oxygen services.

5.15.3 Pressure Gauges and Transducers

Pressure gauges and transducers represent a cleaning challenge because of the small, inaccessible internal passages. In general, customized equipment for flushing is required, such as small diameter tubing to flush Bourdon tubes. Cleaning, inspection, and packaging of pressure gauges and transducers shall conform to those paragraphs in Section 5.15.2 of this specification. The following table lists the current Lewis cleaning specifications for oxygen service gauges and transducers.

LEWIS PERFORMANCE SPECIFICATION

(a) Oxygen-clean certification of pressure gauges and transducers

Hydrocarbon contamination level in solvent wash with IR scan method	< 5 ppm of hydrocarbons in a 50-cm^3 Freon sample
Visual borescope	No scale, heavy rust, or particles

(b) Particles

Particle size, μm	Maximum number/ft^2
<100	Unlimited
100 to 250	1073
251 to 500	27
>500	0

(c) Fibers

Fiber[a] length, μm	Maximum number/ft^2
0 to 500	20
501 to 1000	3
1000 to 1875	1
>1875	0

[a]Up to 25 μm diameter.

5.16 APPENDIX C—RECOMMENDED PROCEDURES FOR GASEOUS OXYGEN TUBE TRAILERS

5.16.1 Operational Requirements

NOTE

(a) Only qualified operators shall perform transfers. Operator certification is described in Section 5.12.2.

(b) While in storage or transport, a properly secured tube trailer should be maintained with all valves in the closed position and with the tailpiece and sample port capped.

(c) A two-man buddy system shall always be in place as specified in Section 5.6.1 of this chapter.

CAUTION

(a) All materials shall be compatible with oxygen use as described in Section 5.9.

(b) Rapid pressurization must be avoided to prevent potential ignition and fire.

(c) Oxygen cleanliness levels must always be maintained. A minor oversight in maintaining cleanliness at the trailer connection point can destroy safe cleanliness levels of the entire oxygen system.

(d) All interconnecting components used for fill, purging, or withdrawal must be free of hydrocarbon and particulate contamination (this includes purge gases).

5.16.2 Tube Trailer Fill

(a) Ground the trailer at the connector located on the bumper.

(b) Secure the trailer doors with latches provided.

(c) Chock/block trailer wheels. Also place a cone or sign at the front of the trailer to indicate that the trailer is connected to the manifold.

(d) Put up the required barricades and signs.

(e) Open the gauge isolation valve to ensure that the supply manifold has maintained pressure and is leak-free. (If the manifold has leaked to atmospheric pressure, cease operations and contact the cryogenic maintenance COTR for proper evaluation and repair.)

(f) Connect the approved transfer hose to the fill tailpiece and supply-side fitting. (Maintain cleanliness of the caps.)

(g) Secure the transfer hose restraining cables to the eyelets provided.

(h) Purge the transfer hose.

(i) Leak-check the hose connections.

(j) Open all tube isolation valves (equalize pressure slowly).

(k) After the transfer hose has been purged and checked, stand clear of the transfer hose and slowly open the trailer manual fill valve.

(l) Ensure that all personnel stand clear of the transfer hose; then slowly, completely open the main gas supply isolation valve (from source) to fill the trailer.

5.16.3 Post-Fill Shutdown

(a) Close the main gas supply isolation valve (from source) to begin the shutdown and disconnect operations.

(b) Close the trailer manual fill valve.

(c) Open the transfer hose vent/purge valve and bleed to atmospheric condition. (Cap fitting.)

(d) Disconnect the transfer hose restraining cable.

(e) Remove the transfer hose from the trailer, and cap the hose and tailpiece ports.

NOTE: If a sample is required, follow the checklist procedures. (Draw the sample gas from the sample panel only.)

(f) Close all tube isolation valves (transfer is complete).

(g) Remove the ground, and close the doors prior to moving the trailer.

(h) Remove the barricades, warning signs, and wheel chocks.

5.16.4 Tube Trailer Withdrawal

(a) Ground the trailer at the connector located on the bumper.

(b) Secure the trailer doors with the latches provided.

(c) Chock/block the trailer wheels. Also place a cone or sign at the front of the trailer to indicate that the trailer is connected to the manifold.

(d) Put up the required barricades and signs.

(e) Open the gauge isolation valve to ensure that the supply manifold has maintained pressure and is leak-free. (If the manifold has leaked to atmospheric pressure, cease operations and contact the cryogenic maintenance COTR for proper evaluation and repair.)

(f) Connect the approved transfer hose to the trailer withdrawal tailpiece and receiving station.

(g) Secure the transfer hose restraining cables to the eyelets provided.

(h) Open all trailer tube isolation valves (equalize pressure slowly).

(i) Leak-check the trailer manifold piping.

(j) Open the receiving station main isolation valve.

(k) Pressure purge the transfer hose assembly and maintain 40 to 100 psi in the transfer line.

(l) Leak-check the transfer hose connections.

(m) Slightly open the manual withdrawal valve on the trailer (valve will expose a 1/8-inch bleed port when open a half turn).

(n) Withdraw personnel from the area of transfer hoses.

(o) Open the trailer emergency shutoff valve from the remote location.

(p) Allow the oxygen receiving station pressure to reach the trailer pressure; then close the trailer emergency shutoff valve.

(q) Fully open the trailer manual withdrawal valve (after a three-quarter turn, the valve will begin exposing the full seat area).

(r) Open the trailer emergency shutoff valve from the remote location to withdraw oxygen for use.

5.16.5 Post-Withdrawal Shutdown

(a) Close the trailer emergency shutoff valve from the remote location.

(b) Close the receiving station main isolation valve.

(c) Vent and purge the transfer hose to atmospheric pressure as specified in the area of use.

(d) Close the trailer manual withdrawal valve.

(e) Disconnect the transfer hose restraining cable.

(f) Remove the transfer hose from the trailer and cap the hose and tailpiece ports. Keep the hose and caps oxygen-clean.

(g) Close all tube isolation valves. (The transfer is secure.)

(h) Remove the ground, and close the doors prior to moving the trailer.

(i) Remove the barricades, warning signs, and wheel chocks.

5.17 APPENDIX D—TECHNICAL CONTRIBUTORS AND REVIEWERS

5.17.1 Technical Contributing and Review Committee

Wayne Thomas	2820	Committee Chairman and editor; Rocket Engine and Test Facility engineering operations
Andrew Aron	7240	Hands-on and supervisory experience; propellant transfer and handling operations
Hank Bankaitis	0151	Aerospace Safety Research and Data Institute engineering experience; oxygen system cleaning
Bruce Block	2800	Safety Committee Chairman of area regularly using propellants
Russell Corso	4220	Launch vehicle and system engineering design
William Klein	2870	Engineering test operations at Plum Brook
John Kobak	8910	Rocket Engine and Test Facility engineering operations
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Additional major technical review of the oxygen chapter was provided by the following members of the Lewis staff:

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Chapter 6. HYDROGEN PROPELLANT

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LIST OF TABLES

Chapter 6. HYDROGEN PROPELLANT

6.1 SCOPE

The Lewis Safety Manual chapter on hydrogen is written to serve as a practical guideline for the safe design and fabrication of systems for, and the safe use of, hydrogen at the Lewis Research Center. A summary of operational hazards along with hydrogen safety and emergency procedures is provided. The chapter is primarily directed at ground-based propellant and similar systems. Material is presented to provide the user with a basis for judgment to extend beyond the ground rules and guidelines established for the safe use of propellant hydrogen. These hydrogen standards and practices are for minimum safety requirements only. More extensive safety precautions should be employed where possible.

The intent is to provide safe, practical guidance that permits the accomplishment of experimental test operations at the Lewis Research Center and that is restrictive enough to prevent personnel endangerment and to provide reasonable facility protection. This chapter is also intended to serve as a tutorial on operational hydrogen safety. An extensive list of references taken from the "Hydrogen Safety Handbook" (Belles 1968) and other sources provides the user a wide variety of additional information. Appendixes A and B detail, respectively, procedures for filling gaseous hydrogen tube trailers and procedures for cleaning hydrogen service systems. Appendix C lists contributors and reviewers.

These guidelines shall govern all aspects of hydrogen handling and usage at the Lewis Research Center and Plum Brook Station. They shall govern whenever there is a conflict between information presented herein and information contained in a reference, except that these guidelines shall in no event be considered as relaxing any occupational safety or health standard imposed by regulation. Section 6.14 presents a list of references that contain rules and procedures to which adherence is mandatory.

Liquid, slush, and gaseous hydrogen shall be stored, handled, and used so that life and health are not jeopardized and so that the risk of property damage is minimized. Hydrogen can be handled safely by adhering to the following guidelines:

(a) Prevent hydrogen leaks by the use of appropriate designs, materials, and procedures.

(b) Keep a constant watch to detect immediately any accidental hydrogen leaks.

(c) Take proper action if a hydrogen leak occurs.

(d) With plentiful ventilation, prevent accumulations of combustible/detonable hydrogen mixtures.

(e) Eliminate likely ignition sources, but suspect the presence of unknown ignition sources.

(f) Handle a hydrogen fire by letting it burn under control until the hydrogen flow can be stopped.

(g) Operate with knowledgeable, trained personnel and use formal procedures.

(h) Subject **all** hydrogen use activities to an independent third-party review.

6.2 DEFINITIONS

See the Glossary (6.18—Appendix D) for terms used in both the oxygen and hydrogen chapters (Chs. 5 and 6).

6.3 POLICY

6.3.1 Hazard Elimination: A NASA Directive

The primary method for resolving hazards shall be to **eliminate them** by proper system design. Hazards that **cannot** be eliminated by proper design shall be controlled by the following methods in the order of precedence listed below:

(a) Designing for minimum hazard

(b) Installing safety devices

(c) Installing caution and warning devices

(d) Developing administrative controls, including special procedures and training

(e) Providing protective clothing and equipment

6.3.2 Approach to Hydrogen Safety

Inherent safety.—Hydrogen systems and operations shall be designed to be inherently devoid of hazards by observing the cardinal axioms of hydrogen safety: **adequate ventilation, leak prevention**, and appropriate elimination of ignition sources.

Fail-safe design.—Redundant safety features shall be incorporated in the system design to prevent a hazardous condition when a component fails. In such incidents the system controls should rapidly shut down the equipment and allow only minimal leakage.

Automatic safety devices.—Leak detection and ventilation shall be automatically controlled. Manual controls of pressure and flow rate shall be constrained by automatic limiting devices. Automation may be utilized in standardized test operations.

Caution and warning devices.—Warning systems shall be installed to monitor those parameters of the storage, handling, and use of hydrogen that may endanger personnel and cause property damage. The warning system shall include sensors to detect abnormal conditions, measure malfunctions, and indicate incipient failures. Data transmission systems for caution and warning systems shall have sufficient redundancy to prevent any single-point failure from disabling the entire system.

Formal procedures.—All hydrogen operations shall be performed according to formal procedures by knowledgeable and trained personnel. Personnel involved in design and operations are required to carefully adhere to the safety standards for hydrogen handling and usage, and must comply with regulatory codes.

Personnel training.—Personnel who handle hydrogen or who design equipment for hydrogen systems must become familiar with the physical and chemical properties of hydrogen as well as the specific hazardous properties of liquid and gaseous hydrogen.

Training should include detailed safety programs for recognizing human capabilities and limitations. Personnel must constantly re-examine procedures and equipment to be sure safety has not been compromised by changes in test methods, equipment deterioration, over-familiarity with the work, or work-related stress.

Safety programs shall be directed toward minimizing the possibilities of accidents, reducing the severity of any accidents that occur, and lowering maintenance and operating costs.

Operator certification.—Operators shall be certified to handle hydrogen and to handle spills and leaks during emergency conditions, in accordance with Section 6.9.2. Operators must be kept informed of changes in facility operations and safety procedures.

Safety review.—All activities associated with hydrogen use shall be subject to an independent, third-party Area Safety Committee review and a permit issued by that Committee. Safety reviews shall be conducted in such typical areas of concern as effects of fluid properties, training, escape and rescue, fire detection, and firefighting. The safety reviews shall include review of the design, operating procedures, and in-service inspections. Hazards analyses shall be performed to identify conditions that may cause injury, death, or property damage.

6.4 PROPERTIES AND HAZARDS OF HYDROGEN

Much of the information in this section has been compiled from NASA SP–3089 (McCarty 1975), National Bureau of Standards Report MN–168 (McCarty et al. 1981), and NASA CR–155743 (Roder 1977).

6.4.1 Selected Safety-Relevant Properties

Ortho and para hydrogen.—The hydrogen molecule exists in two forms, distinguished by the relative rotation of the nuclear spin of the individual atoms in the molecule. Molecules with spins in the same direction (parallel) are called orthohydrogen; those with spins in the opposite direction (anti-parallel), parahydrogen. The two forms have slightly different physical properties but are chemically equivalent.

At or above room temperature, "normal" hydrogen is an equilibrium mixture of 75-percent orthohydrogen and 25-percent parahydrogen. However, at cryogenic temperatures an equilibrium mixture contains predominately the para form. The liquefaction of normal hydrogen produces a liquid containing about 75-percent orthohydrogen, which slowly converts to a parahydrogen with the release of some heat. Catalysts are used to accelerate their conversion in production facilities which produce almost pure parahydrogen in the liquid form.

Gaseous (normal) hydrogen.—Some properties of gaseous hydrogen are as follows:

Reference temperature, °F [°R] (K)	68 [527.7] 293.15
Standard pressure (1 atm) psia (kPa, abs)	14.69 (101.325)
Density,[a] lb/ft^3 (g/m^3)	0.00523 (83.7)
Specific volume,[a] ft^3/lb (m^3/g)	191.4 (0.0119)
Specific heat,[a] Btu/lb-°R (J/g-K)	
C_p	3.425 (14.33)
C_v	2.419 (10.12)
Velocity of sound, ft/sec (m/sec)	4246 (1294)
Heat of combustion, Btu/lb (kJ/g)	
Low	51 596 (119.93)
High	61 031 (141.86)
Stoichiometric composition in air, vol %	29.53
Stoichiometric flame temperature in air, °F (K)	3712 (2318)
Autoignition temperature, °F (K)	
In air	1084 (858)
In oxygen	1040 (833)
Flammability limits, lower and upper, vol %	
Hydrogen-air mixture	4.0 and 75
Hydrogen-oxygen mixture	4.0 and 95
Explosive limits, lower and upper, vol %	
Hydrogen-air mixture	18.3 and 59
Hydrogen-oxygen mixture	15.0 and 90
Minimum spark ignition energy at 1 atm, Btu (mJ)	
In air	1.9×10^{-8} (0.02)
In oxygen	6.6×10^{-9} (0.007)

[a]At 527.7 °R and 1 atm.

Liquid (para) hydrogen.—The following table lists some safety-relevant properties of liquid hydrogen:

Boiling point at 1 atm, °F [°R] (K)	−423.3 [36.49] (20.27)
Vapor pressure at °F [°R], psia (kPa)	
−402 [57.7]	163.0 (1124.3)
−420 [39.7]	23.7 (163.5)
−423 [36.5]	14.7 (101.4)
−433 [26.7]	1.9 (13.1)
Density,[a] lb/ft^3 (kg/m^3)	4.42 (70.79)
Critical density, lb/ft^3 (g/m^3)	1.99 (31.49)
Critical pressure, psia (kPa)	187.5 (1292.7)
Critical temperature, °F [°R] (K)	−400.3 [59.4] (32.98)
Triple point temperature, °F [°R] (K)	−434.8 [24.84] (13.80)
Specific heat,[a] Btu/lb-°R (J/g-K)	
C_p	2.32 (9.69)
C_v	1.37 (5.74)
Heat of vaporization, Btu/lb (J/g)	191.7 (445.59)
Heat of fusion, Btu/lb (J/g)	25.1 (58.23)

[a]At 36.49 °R and 1 atm.

Slush (para) hydrogen.—Slush hydrogen safety-relevant properties are listed in the following table:

State of hydrogen	Temperature		Vapor pressure		Density	
	°R	K	psia	kPa	lbm/ft³	kg/m³
Liquid	36.49	20.27	14.69	101.28	4.42	70.79
Liquid at TP[a]	24.84	13.80	1.02	7.04	4.81	77.04
Slush, 50 mass % solid	↓	↓	↓	↓	5.09	81.50
Slush, 50 vol % solid	↓	↓	↓	↓	5.11	81.77
Solid at TP[a]	↓	↓	↓	↓	5.40	86.50

[a]TP = triple point.

A more complete listing of the thermophysical properties of hydrogen is available in NASA SP-3089 (McCarty 1975) and NBS-NM-168 (McCarty et al. 1981). Although both of these references cover a broad range of properties over a wide range of pressures and temperatures, chapter 3 of the latter provides an in-depth discussion of hydrogen combustibility properties that should be useful to a hydrogen system designer or user.

6.4.2 Typical Potential Hazards

The major hazards associated with hydrogen are fires and explosions, and in the event of contact with the liquid or cold boiloff vapor, frostbite and burns.

Deflagration and detonation.—Hydrogen gas can burn in two modes, as a deflagration or as a detonation.

(a) In a deflagration, the ordinary mode of burning, the flame travels through the mixture at subsonic speeds. This happens, for instance, when an unconfined cloud of hydrogen-air mixture is ignited by a small ignition source. Under these circumstances, the flame will travel at a rate anywhere from ten to several hundred feet per second. The rapid expansion of hot gases produces a pressure wave. Witnesses hear a noise, often a very loud noise, and may say that an explosion occurred. The pressure wave from rapid unconfined burning is not extremely severe, although it may be strong enough to damage nearby structures.

(b) In a detonation, the flame and the shock wave travel through the mixture at supersonic speeds. The pressure ratio across a detonation wave is considerably greater than that in a deflagration. The hazards to personnel, structures, and nearby facilities are also greater in a detonation.

A detonation will often build up from an ordinary deflagration that has been ignited in a confined or partly confined mixture. This can occur even when ignition is caused by a minimal energy source. It takes a powerful ignition source to produce detonation in an unconfined hydrogen-air mixture. However, a confined mixture of hydrogen with air or oxygen can be detonated by a relatively small ignition source.

The pressure ratio across a detonation wave in a hydrogen-air mixture is about 20, as indicated when the wave passes a detector mounted flush in a confining wall. (A pressure ratio of 20 means 300 psi if the mixture is at atmospheric pressure.) When the wave strikes an obstacle, the pressure ratio seen by the obstacle is between 40 and 60. Even larger pressure ratios occur in the region where a deflagration builds into a detonation.

Leakage, diffusion, and buoyancy.—These hazards result from the difficulty in containing hydrogen. Hydrogen diffuses extensively, and when a liquid spill or large gas release occurs, a combustible mixture can form over a considerable distance from the spill location.

Leakage: Hydrogen, in both the liquid and gaseous states, is particularly subject to leakage because of its low viscosity and low molecular weight (leakage is inversely proportional to viscosity). Because of its low viscosity alone, the leakage rate of liquid hydrogen is roughly 100 times that of JP-4 fuel, 50 times that of water, and 10 times that of liquid nitrogen.

Diffusion and bouyancy: The diffusion rate of hydrogen in air is approximately 3.8 times faster than air in air. In a 500-gallon ground-spill demonstration experiment, liquid hydrogen diffused to a nonexplosive mixture after about 1 minute. Air turbulence increases the rate of hydrogen diffusion.

The buoyancy of hydrogen tends to limit the spread of combustible mixtures resulting from a hydrogen release. Although hydrogen vapor is heavier than air at the temperatures existing after evaporation from a liquid spill, at temperatures above −418 °F the hydrogen vapor becomes lighter than air, thereby making the cloud buoyant. (See NSS/FP–1740.11.)

6.4.3 Hazards of Handling and Storage

Safety is improved when designers and operational personnel are aware of accidents that are repeatedly associated with the handling and use of hydrogen. The release of liquid or gaseous hydrogen has resulted in fires and explosions. Such hazards are associated with the formation and movement of a flammable gas-air cloud upon hydrogen release. The dispersion of the cloud is affected by wind speed and wind direction.

Storage and tank failures.—Tank failures resulting in the release of hydrogen may be started by material failures, excessive pressures caused by heat leaks, or failures of the pressure-relief systems. Hydrogen embrittlement is a major material failure threat (see Sec. 6.6.3).

Unloading and transfer leaks.—Unloading and transfer leaks are usually caused by deformed seals or gaskets, valve misalignment, or failures of flanges or equipment. A leak may cause further failures of construction materials.

Collisions during transportation.—Damage to hydrogen transportation systems have caused spills and leaks that resulted in fires and explosions.

6.4.4 Hazardous Properties of Gaseous Hydrogen

Undetectability.—Hydrogen gas is colorless and odorless and not detectable by human senses.

Flammability.—Mixtures of hydrogen with air, oxygen, or other oxidizers are highly flammable over a wide range of compositions. The flammability limits, in volume percent of hydrogen, define the range over which fuel vapors ignite when exposed to an ignition source of sufficient energy.

The flammable mixture may be diluted with either of its constituents until it is no longer flammable. Two limits of flammability are defined: the lower limit, the minimum amount of combustible gas that makes a mixture flammable; and the upper limit, the maximum amount of combustible gas in a flammable mixture.

The flammability limits based on the volume percent of hydrogen in air (at 14.7 psia) are 4.0 and 75.0. The flammability limits based on the volume percent of hydrogen in oxygen (at 14.7 psia) are 4.0 and 94.0. Reducing the pressure below 1 atmosphere tends to narrow the flammability range by raising the lower limit and lowering the upper limit. No mixture of hydrogen and air has been found to be flammable below 1.1 psia.

Autoignition.—Temperatures of about 1050 °F are usually required for mixtures of hydrogen with air or oxygen to autoignite at 14.7 psia. However, at pressures from 3 to 8 psia, autoignitions have occurred near 650 °F.

Hot hydrogen and flash fire.—The primary hazard of using hot hydrogen (1050 to 6000 °F) is that a large leak at temperatures above the autoignition temperature will almost always result in a flash fire. Other safety criteria are the same as for ambient temperature gaseous hydrogen. System construction materials must be suitable for use at the elevated temperatures.

Ignition at low energy input.—**Hydrogen-air mixtures can ignite with very low energy input**, 1/10th that required to ignite a gasoline-air mixture. For reference, an invisible spark or a static spark from a person can cause ignition.

Lack of flame color.—Hydrogen-oxygen and hydrogen-pure air flames are colorless. (Any visible flame is caused by impurities.) Colorless hydrogen flames can cause severe burns.

6.4.5 Hazardous Properties of Liquid Hydrogen

All of the hazards that exist when gaseous hydrogen is present also exist with liquid hydrogen because of the ease with which the liquid evaporates. However, there are additional hazards due to the properties of liquid hydrogen.

Low boiling point.—Liquid hydrogen has a normal boiling point of −423 °F at sea-level pressure. Any liquid hydrogen splashed on the skin or in the eyes can cause serious "burns" by frostbite.

Storage tanks and other containers should be kept under positive pressure to prevent air from seeping in. Condensed and solidified atmospheric air, or trace air accumulated in manufacturing, contaminates liquid hydrogen, thereby forming an unstable mixture. This mixture may detonate with effects similar to those produced by trinitrotoluene (TNT) and other highly explosive materials.

Ice formation.—Vents and valves from storage vessels and dewars may be frozen closed by accumulations of ice formed from moisture in the air. Excessive pressure may then rupture the container and release a potentially hazardous quantity of hydrogen.

Continuous evaporation.—The continuous evaporation of liquid hydrogen in a vessel generates gaseous hydrogen, which must be vented to a safe location.

Trapped liquid.—If liquid hydrogen is confined, for example, in a pipe between two valves, it will eventually warm to the surroundings and cause a significant pressure rise. The pressure of a trapped volume of liquid hydrogen at 14.7 psia, when warmed to 70 °F, rises to 28,000 psia.

Cold gas leak.—At temperatures above −418.6 °F, hydrogen gas is lighter than air at standard temperature and pressure (STP) and tends to rise. At temperatures just after evaporation from the liquid, the vapor is heavier than air and will remain close to the ground until the gas temperature rises.

6.4.6 Hazardous Properties of Slush Hydrogen

All of the hazards that exist with gaseous and liquid hydrogen also exist with slush hydrogen. The combustibility properties of slush hydrogen should not present any greater hazard than those of liquid hydrogen, but there are additional hazards with slush hydrogen.

Low vapor pressure.—The greatest hazard with slush hydrogen systems is the intrusion of air into the hydrogen storage container. Because the vapor pressure of slush hydrogen mixtures is only 1.02 psia, there is always a concern that atmospheric air will leak into the slush system.

Volume expansion on melting and warming.—When the solid hydrogen in slush hydrogen melts and the colder liquid hydrogen warms up to temperatures above the triple point, the volume of the hydrogen increases significantly. A mixture of 50-percent solid (by mass) slush expands more than 15 percent in reaching the density of liquid hydrogen at 36 °R and 1 atm. Sufficient ullage must be available to accommodate the expansion caused by heat input to a storage system over the expected storage time.

Thermal acoustic oscillations.—Thermal acoustic oscillations can be caused by the entrance of the slush mixture into a warmer duct (typically into a gauge line or/and instrumentation tube). The subsequent warming and expansion forces the fluid back into the tank where cooling occurs. The cooling lowers the fluid pressure and causes a resurgence of the slush mixture into the tube. Repetition of this process drives an undamped pressure oscillation which pumps thermal energy into the bulk mixture.

Solid particles in flow streams.—Slush hydrogen piping systems must be designed to prevent solid particles from accumulating and then blocking valve seats, instrumentation ports, and relief valve openings.

Slush hydrogen system air intrusion.—During operation, slush hydrogen systems shall be monitored continuously for the intrusion of air from the atmosphere. A detection warning system design and emergency operation plan shall be presented to the Area Safety Committee.

6.5 SYSTEM DESIGN AND OPERATION

All pressure vessels and systems shall be designed in accordance with the requirements in NMI 1710.3, "Safety Program for Pressure Vessels and Pressurized Systems."

6.5.1 Safety Approval Policy

Before hydrogen facilities, equipment, and systems are constructed, fabricated, and installed, the design safety shall be reviewed and approved by the Area Safety Committee. The safety of hydrogen storage, handling, and use in systems is enhanced when the facility plans, equipment designs, materials, and cleaning specifications are reviewed before construction begins.

6.5.2 Safety Review Requirements

Analysis of hazards.—The Safety Permit request shall include a hazards or failure mode analysis identifying conditions that may cause death, injury, or damage to the facility and surrounding property.

Assessment of final designs.—Reviews of the final drawings, designs, structures, and flow and containment systems shall include a safety assessment to identify potential system hazards and areas of compliance required by local, state, and Federal agencies.

Evaluation of operational procedures.—Operational procedures, along with instrumentation and control systems, shall be evaluated for their capacity to provide the required safety. It may be necessary to develop special procedures to counter hazardous conditions. Equipment performance should be verified by analysis or certification testing. The Area or Process Systems Safety Committee must approve the special procedures and verifications.

Training and certification of operators.—Operators shall be adequately trained and certified prior to operations. Plans for hydrogen safety training shall be presented. See Section 6.9.2.

Development of emergency procedures.—The safety of personnel at and near hydrogen systems shall be carefully reviewed, and emergency procedures shall be developed in the earliest planning and design stages. Advance planning for a variety of emergencies, such as fires and explosions, should be undertaken. The first priority is to reduce any risk to life.

6.5.3 Detection of Combustibles

Hydrogen detectors shall be placed above possible leak points. The use of gathering hoods around the detectors is recommended. The hydrogen detection system must be compatible with systems for fire detection and suppression. The detection units shall not be ignition sources. Details are provided in Section 6.8.

Well-placed, reliable hydrogen detectors are imperative for a safe operating installation. **Detection of liquid hydrogen leaks by observation alone is not adequate.** Although a cloud of frozen air and moisture may be visible, such a cloud is not a reliable indicator of the presence of hydrogen.

The number and distribution of detection points and the time required to shut off the hydrogen at its source should be based on factors such as estimated leakage rates, ventilation, and room volume. In addition, the detection signal should actuate warning alarms and should automatically effect shutoff whenever practicable. Consider sending a high-concentration alarm to the Lewis Fire Department.

Hydrogen detection systems shall be field calibrated at least every 6 months. A record of calibrations shall be maintained for each facility.

6.5.4 Buildings

Type of structure.—In general, hydrogen should be stored, transferred, and handled outdoors where leaks are diffused and more easily diluted to noncombustible mixtures. However, if protection from the weather is required, the type of structure should be selected in the following order of preference:

(a) Roof without peaks; no sides (weather shelter or canopy)

(b) Well-ventilated roof; removable sides

(c) Well-ventilated "expendable" building

(d) Well-ventilated permanent building

The walls and roof should be lightly fastened and designed to relieve at a maximum internal pressure of 25 pounds per square foot without collapse of the structure. Doors shall be hinged to swing outward in an explosion. Any walls or partitions should be continuous from floor to ceiling and securely anchored. At least one wall shall be an exterior wall, and the room shall not open to other parts of the building.

Rooms and test cells containing hydrogen shall be heated only by steam, hot water, or other indirect, passive means.

Construction materials.—The building shall be constructed of noncombustible materials on a substantial frame. The window panes shall be shatterproof glass or plastic in frames. In addition, floors, walls, and ceilings should be designed and installed to limit the generation and accumulation of static electricity and shall have a fire resistance rating of at least 2 hours.

Electrical equipment selection and installation.—Electrical equipment shall, at a minimum, be installed to conform to the "National Electric Code" requirements (NFPA 70) for Class 1, Group B, Division 2. Special considerations shall be given to the selection of wire sizes, types, bonding techniques to prevent arcing, and mechanical damage protection.

Materials for electrical and electronic equipment should be selected in accordance with established specifications such as KSC STD E-0002, "Hazard Proofing of Electrically Energized Equipment."

Installing electrical equipment in purged boxes, using special types of nonarcing electric motors, and locking out specific electrical circuits when hydrogen is present are alternative ways of meeting code requirements.

Electrical wiring and equipment located within 3 feet of a point where hydrogen line connections are regularly made and disconnected, or within 3 feet of a point where hydrogen is vented, shall be Class 1, Group B, Division 1. Electrical wiring and equipment located from 3 feet to 25 feet of a point where connections are regularly made and disconnected, or within 25 feet of a liquid hydrogen storage container, shall be Class 1, Group B, Division 2. See Section 6.7.3 for more information and special exceptions.

6.5.5 Test Chambers

Ventilation.—Any test cell or chamber containing hydrogen system components must be adequately ventilated whenever hydrogen is in the system. The quantities of air, or other means of making the system inert, shall be sufficient to avoid an explosion and should be based on the largest credible volume of the leakage gases relative to the room volume and the time available for instituting corrective measures.

Adequate ventilation must be ensured before hydrogen enters the system, and such ventilation must remain adequate until the system is purged. Do not shut off ventilation as a function of an emergency shutdown procedure. The test cell control system should include interlocking features to prevent operation without adequate ventilation.

Safety-relief devices of containers in buildings should be vented to the outdoors at the minimum elevation that will ensure area safety and where there are no obstructions. **Vents must be located at least 50 feet from air intakes** (OSHA standard, 29 CFR 1910.103). The discharge from outlet openings must be directed to a safe location (see Sec. 6.5.7).

Explosion venting must be provided in exterior walls or in the roof. The venting should be not less than 1 square foot per 30 cubic feet of room volume (see 29 CFR 1910.103).

Hydrogen diffuses rapidly if not confined. At room temperature, hydrogen is the lightest of all gases, only 1/14th as heavy as air; consequently, it rises. Therefore, inverted pockets will trap hydrogen gas. Avoid covers, suspended ceilings, or places where pockets may form and trap hydrogen gas.

Forced air ventilators shall be powered only by devices approved for hydrogen service. Electric motors and drive belts used to open vents, operate valves, or operate fans must be certified as explosion proof for Class 1, Group B use (NFPA 70).

Adequate ventilation to the outdoors must be provided. Inlet openings should be located in exterior walls. Outlet openings should be located at the high point of the room in exterior walls or the roof. Inlet and outlet openings shall have a minimum total area of 1 square foot per 1000 cubic feet of room volume (see 29 CFR 1910.103).

Inert atmosphere.—Test cells or chambers that cannot be ventilated sufficiently to cope with potential hazards may be rendered nonhazardous by providing an inert atmosphere of nitrogen, carbon dioxide, helium, steam, or other nonreactive gas. In such cases it is desirable to have the chamber pressure higher than atmospheric pressure to avoid inward leakage of air. The design shall prevent any possiblity of asphyxiation of personnel in adjacent areas or of personnel who accidentally enter the cell.

Partial vacuum.—Oxidants may be restricted in a test chamber by using a partial vacuum. The vacuum should be sufficient to limit the pressure of an explosion to a value that the tank can withstand. In such a case the chamber must withstand 20 times the maximum operating pressure, except for heads, baffles, and other obstructions in a pipe run, which must withstand 60 times the maximum operating pressure. Because the reaction time during a detonation is so short, ultimate stress values may be used.

Secondary fire protection systems.—Strong consideration should be given to the installation of deluge systems along the top of storage areas. These deluge systems should have both manual and automatic actuation capabilities.

Fire-extinguishing systems should be used to protect manifold piping, relief vents, and transfer pump facilities from **secondary** fires. In addition, rooms containing cryogenic and flammable fluids should be provided with secondary fire and explosion protection. These rooms should have a continuously operating exhaust system with a flow of about 1 cubic foot/minute/square foot (0.3 cubic meter/minute/square meter) of floor area. If a flammable gas is detected at 25 percent of the lower flammability limit, the exhaust capacity should be doubled.

6.5.6 Control Rooms

A blast-proof control room remote from the hydrogen test site is advisable. In any case, control rooms should provide a means to observe (directly or by closed-circuit television) the hydrogen systems. In control rooms where hydrogen use in adjacent test areas could create a hazardous situation, the following must be considered:

Openings to test area.—Any control room window opening into a test cell where excessive pressures or ricocheting fragments could be present must be considered a hazard. If a window is required, it shall be made as small as practicable and shall be of bulletproof glass or the equivalent. A mirror system or a movable steel panel can be used to advantage in some cases.

If wall openings and such cannot be sealed, any hydrogen-containing cell with openings to other rooms should be maintained at a negative pressure relative to the communicating rooms.

Piping systems.—Hydrogen piping must not enter the control room. Any hydraulic or pneumatic control valve must have a double barrier between the hydrogen line and the control room. Manual isolation valves should be used for greater protection. Conduits shall be sealed at the test rig end and be designed to prevent purge gases from entering an occupied area.

Existing gaseous hydrogen transmission lines buried underground in the control areas shall be proof-tested and leak-checked periodically. Buried lines are not allowed for new facilities.

Ventilation.—Inlet openings for room ventilation should be located near the floor level in exterior walls only. Outlet openings should be located at the high point of the control room in the exterior walls or the roof. Both the inlet and outlet vent openings must have a minimum total area of 1 square foot per 1000 cubic feet of room volume.

Title 29 CFR 1910.103 (par. (b)(2)(ii)(d)(5)) prohibits locating hydrogen systems of more than 3000 cubic feet within 50 feet of intakes for ventilation or for air-conditioning equipment and air compressors. Compliance with this restriction is required.

There are stricter limits for liquid hydrogen; for all quantities, the minimum distance to air compressor intakes, air-conditioning inlets, or ventilating equipment shall be 75 feet measured horizontally.

Particular attention should be paid to the ventilation or air source for control rooms that may, in an emergency, be enveloped in hydrogen gas or the products of combustion. Undetected hydrogen is responsible for a large number of fires and explosions.

To ensure that inert gases are prevented from escaping into control room areas,

(a) Do not pipe inert gases into tightly sealed shelters if there is a possibility of accidental release and suffocation from lack of oxygen

(b) Seal purged electrical gear and conduits from personnel shelters

(c) Make sure that instrumentation and gas sampling systems cannot provide a leak path for inert gases to the control area

6.5.7 Hydrogen Vessels

General requirements.—The following are design requirements for the safe storage and use of hydrogen.

(a) All hydrogen vessels or containers other than piping shall comply with the following:

- Storage or stationary containers shall be designed, constructed, and tested in accordance with appropriate requirements of Section VIII of the "ASME Boiler and Pressure Vessel Code" for unfired pressure vessels.

- Portable containers shall be designed, constructed, tested and maintained in accordance with U.S. Department of Transportation (formerly Interstate Commerce Commission) specifications and regulations (49 CFR).

(b) All piping and systems shall conform to Section 6.5.10.

(c) Fixed storage vessels and propellant trailers shall be located in accordance with the appropriate quantity-distance tables as specified in Section 6.11.

(d) Amounts of hydrogen in test rigs and special vessels inside buildings should be kept at a minimum as approved by the Area Safety Committee (see Sec. 6.11).

(e) All hydrogen vessels shall be protected from potential sources of shrapnel. Barricades should be installed near the test area to protect the dewar from blast fragments or from disintegrating high-speed machinery. Housings for high rotational speed equipment may be designed as shrapnel shields between the rig and the vessel.

(f) Combustible materials shall be allowed in the hazardous areas only when they are required for test purposes. Otherwise, the onsite materials restrictions of ANSI/NFPA 50A and 50B shall be followed.

(g) Piping carrying hydrogen to the test vessels from the dewars, trailers, and storage vessels should be installed above ground.

- Hydrogen lines for new construction shall be installed above grade or in open trenches covered with grating.

- Lines crossing under roadways shall be installed in concrete channels covered with an open grating.

- Lines carrying liquid hydrogen should be insulated to prevent the condensation of atmospheric air.

(h) Hydrogen transport dewars and trailers shall be kept outdoors and located so that hydrogen cannot leak into any building.

(i) Hydrogen transport trailer parking areas shall be barricaded and have warning signs posted whenever a loaded hydrogen gas trailer or mobile dewar is present. Warning signs are required and shall state "Gas (or Liquefied) Hydrogen—Flammable Gas—No Smoking or Open Flame."

(j) Adequate lighting should be provided for nighttime transfer operations. The electrical wiring and equipment shall comply with established safety code requirements as specified in Section 6.7.

(k) Vessels shall be tagged and coded with the following information:

- Capacity
- Contents
- Day, month, and year of last hydrostatic test
- Hydrostatic test pressure
- Manufacturer
- Maximum allowable working pressure
- NASA or manufacturer part number

(l) Facility file records of tests on vessels, piping, and components shall be maintained.

Fixed storage systems for liquid hydrogen.—Surfaces exposed to the cryogen shall be constructed of materials that do not tend toward low-temperature embrittlement. Generally, face-centered-cubic metals and alloys such as aluminum, copper, nickel, and austenitic stainless steels are used. The outer wall or vacuum jacket may be fabricated from mild steels (see Sec. 6.6).

The tank outlet and inlet markings should designate whether the working fluid is vapor or liquid. The hazard potential of opening the system will differ significantly for pressurized vapors and liquids. Wherever possible, avoid storing liquid hydrogen in containers with bottom openings, thereby preventing an uncontrollable leak path if a valve or connector should fail.

Insulation shall be designed to have a vapor-tight seal in the outer jacket or covering, to prevent air condensation and oxygen enrichment within the insulation. Condensed air in the insulation system may expand explosively as it reverts to a gas when the liquid hydrogen is emptied from the tanks or pipes.

The roadways and surfaces of areas below hydrogen piping from which liquid air may drop shall be constructed of noncombustible materials such as concrete.

Mobile storage systems for liquid hydrogen.—The design of mobile storage systems shall conform to the applicable specifications herein and to Department of Transportation (DOT) Hazardous Materials regulations, listed in Title 49, Code of Federal Regulations, Parts 170 to 180. In addition, dual rupture disks shall be required on trailers used for NASA liquid hydrogen operations.

Recommended procedures, driver training, and basic operations are detailed in NSS/FP–1740.11.

Fixed and mobile storage systems for gaseous hydrogen.—Large volumes of gaseous hydrogen shall be stored outdoors in mobile or fixed cylinders. Design guidelines for these systems are as follows:

(a) Use recommended materials as listed in Section 6.6.

(b) Do not make unrelieved penetrations to the side walls; if a pressure gauge is needed, consider entry through the forged heads.

(c) Include a passageway for regular visual inspection in larger diameter vessels.

(d) Do not use T-1 steel or cast iron.

Gas tube trailers shall have physically specific connecting fittings to prevent cross connection to the incorrect gas manifold. In addition to the manually operated main shutoff valves, these gas tube trailers should be equipped with remotely operated, normally closed safety shutoff valves that require maintained power to remain open. They shall automatically return to fully closed upon the removal of the control power. The valve cabinets should be well ventilated, and the trailer valve cabinet doors should be fully opened when in service.

Common gas facilities for both fuels and oxidants are not recommended. If common facilities are absolutely necessary, however, the installation must have proper purging procedures, blocking valves, venting systems, and most importantly, personnel technically trained in gas handling. Use of common gas facilities for both fuels and oxidants will require a locally granted waiver.

Fixed storage vessels shall be located in accordance with the approved gaseous hydrogen quantity-distance tables (see Sec. 6.11).

Vessel valves.—Valves and other components subjected to liquid hydrogen or cold gas flows shall be suitable for cryogenic service. All liquid hydrogen vessels and mobile dewars shall be equipped with automatic shutoff valves. Manually operated valves may be used under the following conditions:

(a) The loading operations and valves are attended by personnel using the buddy system, if this procedure has been approved by the Area Safety Committee.

(b) The pressure of the dewar does not exceed the normally designed operating pressure, which may be from 25 to 55 psia.

(c) Vessels used as components of a test facility have remote-operating failsafe shutoff valves with manual override to be used if the power fails.

(d) For protection against the hazards associated with ruptures, rupture disks or relief valves are installed in all enclosures that contain liquid or that can trap liquids or cold vapors. Rupture disks or relief valves may not be necessary if the liquid or the cold vapor trapped between two valves can be relieved through one of the valves at a pressure less than the design operating pressure.

Vessel supports for mobile dewars.—The design and construction of supports for inner vessels, as well as for piping systems, should meet structural and thermal operational requirements.

For over-the-road trailers (tank motor vehicles) all supports to inner vessels and to load-bearing outer shells should be attached by pads of materials similar to that of the inner vessel or outer shell, respectively, and by load rings or bosses designed or gussetted to distribute the load.

Trailers shall be provided with at least one rear bumper designed to protect the tank and piping in the event of a rear-end collision and to keep any part of another vehicle from striking the tank. The design should allow the force of a rear-end collision to be transmitted directly to the chassis of the vehicle. See NFPA-385-1 for other information on tank motor vehicles for flammable and combustible liquids.

Transfer connections.—Connectors must be keyed, sized, or located so that they cannot be cross-connected, thereby minimizing the possibility of connecting incompatible gaseous fluids or pressure levels. The connectors and fittings to be disconnected during operations should have tethered end plates, caps, plugs, or covers to protect the system from contamination or damage when it is not in use.

Liquid hydrogen connections: Vessels shall be connected to rigidly mounted test facility piping with supported and anchored flexible metal hose that is insulated for low-temperature service at the desired pressure. Other requirements for liquid hydrogen conections follow:

(a) Recommendations for flexible hoses include a maximum allowable slack of about 5 percent of the total length, per 29 CFR 1910.103. For even greater safety, the hose restraints should be at least 50 percent stronger than the calculated impact force on an open line moving through the flexure distance of the restraint.

(b) Sharp bends and twists should be avoided in the routing of flexible hose. A minimum of 5 times the outside diameter of the hose is considered acceptable as a bend radius.

(c) The pressure range of the transfer equipment should be rated equal to or greater than the tanker design pressure. Flexible hose delivering a high-pressure fluid should be secured at both ends.

(d) If condensation or frost appears on the external surface of the vacuum jacketed hose during use, the jacket vacuum should be checked. The hose should be removed from service and repaired if the vacuum is above 100 torr.

(e) Gasket materials used shall be suitable for this cryogenic service. Loose-fiber gasket material that can be readily fretted should not be used since the loose particles may contaminate the system. Properly sized gaskets shall be used.

(f) O-rings and O-ring grooves shall be matched properly for the design service conditions.

Gaseous hydrogen connections: Gaseous hydrogen connections from over-the-road tube trailers to facility supply systems shall conform to the specific safety design and material requirements specified by the Lewis Facilities Operations Division. General requirements are as follows:

(a) Piping, tubing, and fittings shall be suitable for hydrogen service at the pressures and temperatures involved. Preferably, the joints in piping and tubing should be made by welding.

(b) Flexure installations 6 feet long or longer that are to be used at high pressures shall be designed with a restraint on both the hose and the adjacent structure at 6 feet intervals and at each end to prevent whiplash in the event of a burst.

Vent systems.—All dewars and storage and flow systems shall be equipped with unobstructed vent systems designed to dispose of hydrogen safely and to prevent the entry and accumulation of atmospheric precipitation. (See Sec. 6.5.5 for information on ventilation and Sec. 6.5.16 for vent systems design.) In addition, note the following:

(a) Over-the-road dewar vent systems should be connected to a building hydrogen vent system when the dewar is parked near a building.

(b) Gas or liquid trapped in vessels or transfer lines by emergency shutdown conditions shall be released or vented in a safe manner.

(c) Cabinets and housings containing hydrogen control or operating equipment shall be adequately ventilated or purged.

6.5.8 Overpressure Protection of Storage Vessels and Systems

General requirements.—Safety devices (safety relief valves and/or rupture disks) shall be installed on tanks, lines, and component systems to prevent damage by overpressure. The required relieving capacity of any pressure-relief device shall include consideration of all the vessel and piping systems it protects. Such safety devices must be reliable, and the settings must be secured by suitable devices against accidental alteration. Stationary hydrogen containers should be equipped with safety devices sized in accordance with CGA Pamphlet S-1.3.

Items (a) to (j) in the following list apply to gaseous hydrogen and liquid hydrogen service. Items (k) to (n) apply solely to liquid hydrogen service.

(a) The relief or safety valves shall be set so as to limit the maximum pressure rise during relief to no more than 10 percent above the maximum allowable working pressure.

(b) The safety relief valve shall be a direct spring or deadweight-loaded type; however, pilot valve control or other indirect operation of safety valves is allowed if the design permits the main unloading valve to open automatically at the set pressure or less and if this valve can discharge at its full rate capacity should the pilot or auxiliary device fail.

(c) The "begin-to-relieve" pressures of relief devices shall be set as specified by the ASME "Boiler and Pressure Vessel Code," Section VIII. Relief devices shall be sized to exceed the maximum flow capacity of the pressure source.

(d) The openings through all pipe fittings between piping and tanking systems and their pressure-relief device shall at least equal the area of the device inlet. The upstream system shall not allow the pressure drop to reduce the relief capacity to below that of the required capacity or to adversely affect the proper operation of the pressure-relief device. The pressure drop shall not exceed 5 percent of the set pressure.

(e) When discharge lines are long, or where outlets of two or more valves having set pressures are connected to a common line, the effect of the backpressure that may develop when both valves are in operation should be considered.

(f) Discharges directly to the atmosphere shall not impinge on other piping or equipment and shall be directed away from platforms and other areas used by personnel, since the discharge gas may ignite and burn.

(g) Reactions on the piping system due to actuation of pressure-relief devices must be considered, and adequate strength must be provided to withstand these reactions.

(h) Stop valves shall not be installed between the tanking and piping systems being protected and their protective devices, or between the protective devices and the point of discharge, without approval of the Area Safety Committee.

- If stop valves are closed while the equipment is in operation, an experienced operator shall continuously observe the operating pressure and should be prepared to relieve the system if an overpressure occurs.

- Stop valves may be used in pressure-relief piping if they are constructed or positively controlled so that closing the maximum possible number of stop valves does not lower the capacity of the unaffected pressure-relief devices to below the required capacity.

(i) The existence of a pressure switch to cut off the source of high pressure does not eliminate the need for the primary protective device.

(j) The primary protective device should be located as close as possible to the high-pressure source.

(k) All materials used in the construction of overpressure protection systems shall be suitable for the operating temperature of the tanking and piping systems. Pressure-relief devices and the inlet and discharge piping shall be designed and installed to minimize moisture accumulation and ice buildup from atmospheric condensation, which could cause them to malfunction. The pressure-relief devices shall preferably be located to relieve vapor and gas rather than liquid.

(l) A rupture disk or relief valve should be installed in every section of a line where liquid can be trapped. This trapping condition exists most often between two valves in series. A rupture disk or relief valve may not be required if at least one of the valves will, by its design, relieve safely at a pressure less than the design pressure of the liquid line. This procedure is most appropriate in situations where rupturing of the disk could create a serious hazard.

(m) If it is possible to vent liquid hydrogen through it, the primary relief device should be designed and sized to accommodate liquid flow.

(n) Each section of a vacuum jacket system shall be protected with a relief device. This device, which may be a rupture disk, should limit the pressure in the annulus to not more than 10 percent above the lesser of the external design pressure of the inner line or the design pressure of the jacket.

Failure modes.—The following failure modes must be considered in the design and operation of protective pressure-relief systems:

(a) The pressure buildup associated with the phase change or temperature rise caused by the normal heat leak into the section

(b) Overpressure caused by abnormal conditions peculiar to liquid hydrogen tankage and piping, such as insulation failures

(c) The overpressure potential associated with connection to a high-pressure source of any type

Rupture disks and relief valves.—Rupture disks are designed to break at a specific pressure and temperature. The tensile strength of the disk and, thus, the pressure at which it will rupture are affected directly by the temperature. To ensure proper functioning, disks should be located in zones with constant temperature at operating pressures. For cyclic operations, vacuum supports may be necessary to prevent reverse buckling and disk fatigue.

When rupture disks are used, it is recommended that the stamped bursting pressure be sufficiently above the intended operating pressure, to prevent premature failure of the rupture disks due to fatigue or creep. Other guidelines are as follows:

(a) Only those materials suitable for the working conditions are to be used for safety relief devices. Devices shall be rated as specified in the appropriate ANSI/ASME and CGA codes and standards.

(b) Relief valves and rupture disks shall be recalibrated and recertified in accordance with instructions and time periods specified in Chapter 7 of this Manual.

(c) A rupture disk may be installed upstream of a relief valve provided that the disk rupture pressure is less than the maximum allowable working pressure; methods of detecting disk failure or leakage are present; the sizing is correct; and there is no chance for the disk failure to interfere with the operation of the relief valve.

(d) Under approved conditions rupture disks may be installed downstream of relief valves, to prevent mixing of the atmosphere and the escaping hydrogen during temporary low-flow overpressure situations or to prevent ice from building up in the relief device. In these circumstances, the rupture pressure must not exceed 20 percent of the set pressure of the relief device.

(e) The failure of a rupture disk protecting a liquid hydrogen dewar vessel can create a hazardous condition. Replacement of single rupture disks requires extremely careful planning and should be done cautiously **only** after the vessel has been emptied and purged.

(f) Supplemental pressure-relief devices shall be installed to protect against excessive pressures created by exposure to fire or other unexpected sources of external heat. These special secondary relief valves shall be set at 110 percent of the maximum allowable working pressure, but shall be capable of limiting the pressure to not more than 90 percent of the test pressure under emergency conditions.

(g) Transient pressure surges associated with chilldown flow instabilities, water hammer, and cavitation shall be considered in designing and installing supplemental relief systems.

(h) The capacity rating of the cryogenic relief devices, as determined from the established ASME, American Petroleum Institute (API), or Compressed Gas Association (CGA) equations, may have to be modified to satisfy the flow requirements for the valve or other safety device for operation in all possible fluid regimes (e.g., subcooled liquid, saturated liquid, superheated fluid, saturated vapor, and supersaturated gas).

6.5.9 Protective Barricades, Dikes, and Impoundment Areas

Purpose of barricade.—Barricades serve two purposes: to protect uncontrolled areas from the effects of a storage vessel rupture and to protect the storage vessel from the hazards of adjacent or nearby operations. Barricades are often needed in hydrogen storage areas to shield personnel, storage vessels, and adjoining areas from fragments if a rupture should occur where adequate separation distance is not available.

Barricades are mainly effective against fragments and only marginally effective in reducing overpressures at extended distances from the barricade. They should be located adjacent to the expected fragment source and in a direct line-of-sight between it and the facility to be protected. If this is not possible, a barricade may be placed adjacent to the facility to be protected and in a direct line-of-sight between it and the expected fragment source.

Since pump facilities are usually required at hydrogen storage and use facilities, barricades shall be included in the design to provide protection against pump failures that could yield shrapnel. (See Sec. 6.11.6 for more information.)

Types of barricades.—The most common types of barricades are earthworks (mounds) and earthworks behind retaining walls (single revetted barricades). A mound is an elevation of naturally sloped dirt with a crest at least 3 feet wide. Single revetted barricades are mounds modified by a retaining wall on the side facing the potential hazard source.

Barricade design.—The proper height and length of a barricade shall be determined by line-of-sight considerations. Barricades, when required, must block the line-of-sight between any part of equipment from which fragments can originate and any part of the protected items. Protection of a public roadway shall assume a 12-foot high vehicle on the road.

Barricades must not completely confine escaped hydrogen, or detonation rather than simple burning might result. One-cubic-meter liquid hydrogen spill tests conducted inside an open-ended (U-shaped) bunker without a roof produced detonation of the hydrogen-air mixture. Explosive limits of hydrogen in air are 18.3 to 59 percent by volume (Strehlow and Baker 1975; and Cloyd and Murphy 1965).

Confinement of liquid and vapor.—A rapid liquid hydrogen spill (e.g., from the rupture of a storage vessel) results in a ground-level flammable cloud for a brief period. The quick change from a liquid to a vapor and the thermal instability of the cloud cause the hydrogen vapors to mix quickly with air, disperse to nonflammable concentrations, warm up, and become buoyant (NSS/FP–1740.11, Appendix).

To control the travel of liquid and vapor due to tankage or piping spills, the facility should include impoundment areas and shields for diverting spills. The loading areas and the terrain below transfer piping should be graded toward an impoundment area, and the surfaces within these areas should be cleaned of flammable materials. Crushed stone in the impoundment area can provide added surface area for liquid hydrogen dissipation.

Planned installations should eliminate possible confining spaces created by the equipment, tankage, and piping. Flames in and around a collection of pipes or structures can create turbulence that causes a deflagration to evolve into a detonation, even in the absence of gross confinement.

Where it is necessary to locate liquid hydrogen containers on ground that is level with or lower than adjacent storage containers for flammable liquids or liquid oxygen, suitable protective means should be employed (such as dikes, curbs, and sloped areas) to prevent accumulation of other liquids within 50 feet of the liquid hydrogen containers (ANSI/NFPA 50B).

No sewer drains shall be located in an area where a liquid hydrogen spill could occur.

6.5.10 Piping Systems

General requirements.—All pressure, vacuum, and vent piping for both gaseous and liquid hydrogen systems shall conform to the American National Standards Institute/ American Society of Mechanical Engineers "Code for Pressure Piping," B31, specifically the section on "Chemical Plant and Petroleum Refinery Piping," designated as ANSI/ ASME B31.3.

In addition, gaseous hydrogen systems shall also conform to the special requirements of ANSI/NFPA 50A, "Gaseous Hydrogen Systems at Consumer Sites," and liquefied hydrogen systems, to the special requirements of ANSI/NFPA 50B, "Liquefied Hydrogen Systems at Consumer Sites."

(a) Piping materials and allowable stresses shall conform to values listed at metal temperature in ANSI/ASME B31.3, Appendix A.

(b) Materials recommended for hydrogen piping and system components are described in Section 6.6, but those selected shall be listed as having an allowable stress value at the metal temperature range in ANSI/ASME B31.3 Appendix A. Materials for operation at lower temperatures shall meet the requirements of Chapter III of B31.3.

(c) Piping and pressure-containing components shall be designed in accordance with ANSI/ASME B31.3; shall be legibly marked; shall have special design considerations based on location; and shall be located no closer than the distances specified in ANSI/NFPA 50A for gaseous systems or 50B for liquefied systems.

(d) Proof- and leak-testing shall be performed in accordance with Chapter 7 of this Manual.

(e) Piping systems should include safeguards for protection from accidental damage and for the protection of people and property against harmful consequences of vessel, piping, and equipment failures.

(f) Piping for liquid or gaseous hydrogen shall not be buried. Below-grade piping shall be placed in open trenches with removable grating.

(g) The piping shall be periodically proof-tested as part of the recertification of the pressure vessel and system according to Chapter 7 of this Manual.

(h) The lines should be tagged and coded to indicate contents (liquid or gas), direction of flow, and maximum allowable working pressure.

(i) Hydrogen propellant lines shall **NOT** be located **beneath** electric power transmission lines. Certain excepted electric wiring systems are permitted **above** hydrogen propellant lines; these shall comply with Sections 501-4, 511-6, and 515-4 of the "National Electric Code" (NFPA 70).

Liquid hydrogen piping requirements.—Most liquid hydrogen lines are vacuum jacketed to reduce heat input and to prevent the condensation of atmospheric air. This vacuum jacket system should be separate from the vacuum systems of the main hydrogen storage and handling systems. The jacket design shall consider the inner line's thermal flexibility and allow the jacket to follow its natural thermal displacement. Other guidelines are as follows:

(a) Bellows expansion joints are usually placed in the jacket. At installation, bellows shall not be extended or compressed to make up deficiencies in length or alignment.

(b) The inner pipe is usually supported within the vacuum jacket by spacers in the annulus. The design and location of the spacers must accommodate the thermal loading during cooldown, the forces transmitted to the jacket, and the deadweight of the inner line under all imposed conditions.

(c) Since a liquid hydrogen system built of stainless steel has a thermal contraction of about 0.35 percent from ambient temperature to −423 °F, long runs of piping require support at intervals, to allow for the axial motion and restrain the lateral and vertical motion.

(d) Piping systems shall be sufficiently flexible to prevent failures or leaks due to thermal expansion or contraction. Consideration shall be given to the following:

- Overstress or fatigue of piping, supports, or anchors
- Leakage at joints
- Detrimental stresses or distortion in piping or in connected equipment resulting from excessive thrusts and moments in the piping
- Resonance with imposed or flow-induced vibrations
- Cryogenic bowing on the bottom of the pipe (especially important in designing pipe guides and main and intermediate anchors for bellows expansion joints because forces are normally generated by bowing)

(e) Each section of cryogenic piping between valves should be considered as a pressure vessel with a source of external energy such as a heat leak into the line. Each of these sections must be equipped with protective devices to control overpressures, particularly those caused by insulation failures and fires.

(f) Nonvacuum insulation on liquid hydrogen piping should be fire rated "self-extinguishing." Other fluid lines in close proximity to the liquid hydrogen lines should also be protected from freezing.

(g) Low points (traps) on liquid discharge piping should be avoided to prevent both the accumulation of contaminants and the trapping of liquid. Contamination of liquid hydrogen by solid air or oxygen-enriched air can result in serious accidents.

(h) Uninsulated piping and equipment operating at liquid hydrogen temperatures shall be installed away from (and not above) asphalt or other combustible surfaces.

Gaseous hydrogen piping requirements.—Materials for gaseous hydrogen piping systems and components shall be suitable for the stress, temperature, pressure, and exposure conditions. Recommended materials are discussed in Section 6.6.

Embrittlement of the materials by gaseous hydrogen must be considered in designing and constructing the system. Conditions that contribute to hydrogen environment embrittlement failures include temperature, pressure, and hydrogen purity. Failures of piping and components are most severe at room temperature, at high pressure, and with very pure hydrogen.

High-pressure gas manifolds are to be of welded construction wherever possible. Expansion or contraction shall be accommodated, and adequate supports shall be provided.

6.5.11 Fittings, Connections, Joints, and Equipment

Threaded joints.—Threaded joints with a suitable thread seal are acceptable for use in gaseous hydrogen systems but are to be avoided in liquid hydrogen systems. However, any compounds or lubricant used in threaded joints must be suitable for the service conditions and should not react chemically with either hydrogen or the piping materials.

Threaded joints used inside a building are to be seal welded to prevent leaks. When threaded joints are seal welded, they must be free of seal compound. An acceptable alternate procedure is to mount threaded components inside a purged metal box and vent the box outdoors according to Section 6.5.16.

Mitered joints.—Mitered joints may be used in liquid hydrogen piping systems under the following conditions:

(a) A joint stress analysis has been performed and the Area Safety Committee has given its approval.

(b) Full-penetration welds are used in joining miter segments.

Tube fittings.—Tube fittings are used primarily for gaseous hydrogen service. Careful engineering design evaluation shall be applied before using this type of fitting in liquid hydrogen service; carbon steel is not suitable for liquid hydrogen service.

The following table shows the maximum diameters and pressures for fittings of various materials and types.

Fitting type	Maximum diameter, in.	Maximum pressure, psig
	Steel and stainless steel	
Flared and flareless	1	Industrial practice
Flared and flareless	1.5	125
	Aluminum	
Flareless	Not permitted	Not applicable
Flared	0.375	Industrial practice
	Copper base	
Flared and flareless	Industrial practice	Industrial practice

In addition, the following rules apply:

(a) Flanged or fusion-welded joints shall be the standard rule for steel tubes larger than 1 inch in diameter and for pressures greater than 125 psig. It may be necessary in some cases involving pressures higher than 125 psig and tubes larger than 1 inch to use flared fittings. These cases are to be considered special and shall be submitted to the Area Safety Committee for approval. Use of flared fittings requires high-quality tools and workmanship. For tubes, power machines are necessary to obtain the required quality of flare.

(b) Only stainless steel shall be used where fire hazards exist with hydrogen, oxygen, and hydraulic systems. Aluminum or copper would melt and release the hydrogen, thereby increasing the extent of the damage.

(c) Fittings shall be tightened in accordance with the manufacturer's recommended limits.

Flanges.—Flanges for hydrogen systems shall be designed and manufactured in accordance with "Pipe Flanges and Flanged Fittings," ANSI/ASME B16.5. The Area Safety Committee may approve the use of other ANSI/ASME flange standards if appropriate. Other requirements for flanges are

(a) Blanks to be used only for test purposes shall be designed in accordance with ANSI/ASME B16.5, except that the design pressure shall be at least equal to the test pressure. The allowable stress shall not exceed 90 percent of the code-specified minimum yield strength of the blank material.

(b) Where flanges use a flat, soft aluminum gasket, the flange faces shall be raised and concentrically serrated. NASA drawing CF 623551 shows flange serration detail for ambient and cryogenic assemblies using aluminum flat face gaskets. NASA drawing CC 621647 shows aluminum flat face gasket design.

A dual serration flange design that may be useful in hydrogen slush vacuum piping systems is shown in Plum Brook drawing PF 22981.

Grayloc hub connections have been successfully used at the Rocket Engine Test Facility in gas and liquid service for both hydrogen and oxygen for the past 20 years. These Grayloc hub designs are shown in NASA drawing CF 639265.

Flexible hose.—All flexible hoses pressurized to greater than 165 psia shall be restrained at intervals not to exceed 6 feet and shall have an approved restraint device attached across each union or hose splice and at each end of the hose. The restraint devices shall be secured to an object of adequate strength to restrain the hose if it breaks.

Approved restraint devices are devices designed for the purpose, such as the Kellums hose containment grips. Hose containment methods and devices that differ from those noted in the "Kennedy Space Center Safety Practices Handbook," Volume 2 (KHB-1710.2) must be approved by the Safety Assurance Office or the Area Safety Committee.

Transfer line flexible hoses carrying liquid hydrogen should be vacuum jacketed with an exterior flexible hose rated for this service.

Expansion joints.—Bellows type expansion joints used in hydrogen piping systems may be convoluted or toroidal and may or may not be reinforced. (Lap-welded tubing shall not be used.)

Although a fatigue life able to withstand the full thermal motion cycles shall be a design requirement, in no case shall the life of the bellows be less than 1000 full thermal movement and pressure cycles.

Expansion joints shall be marked to show the direction of flow. Unless otherwise stated in the design specifications, flow liners shall be provided when flow velocities exceed the following values:

Expansion joint diameter, in.	Flow velocity, ft/sec	
	Gas	Liquid
≤ 6	4	2
>6	25	10

In all piping systems containing bellows, the hydrostatic end force caused by pressure, as well as the bellows spring force and the guide friction force, must be resisted by rigid external anchors or a tie rod configuration.

The expansion joints shall be installed in locations accessible for scheduled inspection, and all circumferential welds should be 100 percent radiographed to assure quality welds.

Pressure tests of piping systems should be performed with the bellows expansion joints installed in the line with no additional restraints so that the expansion joint cross connections or external main anchors carry the full pressure load. These tests shall not be performed until all anchors and guides are securely in place.

Pipe support systems.—The design of pipe-supporting elements shall account for all concurrently acting loads transmitted into such supports. These loads, in addition to weight effects, should include loads introduced by service pressure and temperature, vibration, wind, earthquake, shock, and thermal expansion and contraction. Furthermore, the following requirements apply:

(a) All supports and restraints shall be fabricated from materials suitable for the service conditions. Any attachments welded to the piping shall be of a material compatible with the piping and service conditions. The stress of materials in all parts of supporting and restraint assemblies shall not exceed the allowable ASME Code stress at the operating temperature.

(b) Pipe supports for thin wall vacuum jacketed pipe should be located at points on the jacket with doubler plates or load-spreading saddles.

Equipment assemblies.—Valves, gages, regulators, and other accessories shall be suitable for gas or liquefied hydrogen service and for the pressures and temperatures involved.

6.5.12 Gaskets and O-Rings

Selection.—The design engineer must consider the performance of materials subjected to the pressures and temperatures to which the hydrogen system may be exposed. Even with proper design and assembly, subtle changes due to fatigue, temperature changes, and vibration may reduce gasket material resilience and cause a leak. Torque loss becomes a serious consideration and requires a gasket material that is minimally affected by thermal gradients.

The contact surface finish of the assembly face and the type of assembly affect gasket selection. The bolting must be adequate to produce the degree of gasket flow required for a pressure-tight seal.

Correct installation of the gasket is of major importance to avert subsequent leaks. In liquid hydrogen applications, it may be necessary to re-tighten bolts to compensate for thermal forces.

Metal O-rings.—Using similar materials in the O-ring and flange prevents leakage from unequal contraction of dissimilar metal materials. Thus, type 321 stainless steel O-rings with a coating such as Teflon or silver should be used in stainless steel flanges with stainless bolts, and Teflon-coated aluminum O-rings should be used in aluminum flanges.

Surface finishes in the O-ring groove and contact area should be at least 32 microinches rms. All machine or grind marks **should** be concentric.

Gaskets for flanges.—For high pressures or lower temperatures a raised face flange is recommended. Concentrically serrated faces have worked successfully. Metallic gaskets can be used with raised-face flanges. A tongue-and-groove flange is desirable for most gasket materials subjected to higher pressures. If a plastic such as Teflon is used, a confining flange is mandatory. See Flanges under Section 6.5.11 for NASA design drawings for serrated installations.

Materials such as dead soft aluminum and Durabula have been successfully used as flat gasket stock. Stainless steel has been used in tongue-and-groove installations. (See Sec. 6.6 also.)

6.5.13 Fabrication of Joints and Pipes

The welded joint, because of its simplicity and high reliability, is recommended for both gaseous and liquid hydrogen system pipes and tubes.

In addition to its high structural efficiency and fatigue resistance, a properly made weld is often the only fused joint that has a melting point nearly equal to that of the bulk structure. This is a potential safety hazard; a joint that melts in an accidental fire can release additional large quantities of fuel.

Certain brazed, flanged, threaded, socket slip, or compression fitting joints may also be used for appropriate design and use conditions in hydrogen service per ANSI/ASME B16.

Welding joints.—The type of weld to be used is generally determined by factors other than the system's hydrogen use. Tungsten inert-gas arc welding is generally preferred for joining light-gauge stainless steel and is often preferred for construction of vacuum-jacketed equipment. Conventional arc techniques are also used extensively, especially for heavy-gauge material, where cost is a strong factor. Filler material and stress-relieving requirements are determined by the parent material to be joined. Normal standard practices should be followed.

Marking: Identification on welds, unless specified otherwise by the engineering design, should be marked with crayon or paint that is not conducive to corroding the base metal. To preclude offgassing, no markings should be allowed on the inner pipe of vacuum-jacketed joints. Welds, including additions of weld metal for alignment, should be made in accordance with a qualified procedure and by qualified welders.

Welding responsibility: NASA is responsible for the welding done by NASA personnel and shall conduct the required tests to qualify the welding procedures and the welders. The Lewis Fire Department is to be notified prior to any welding operation.

Contractors are responsible for welding done by their personnel. An employer shall not accept a performance qualification made by a welder for another employer without the inspector's specific approval. If approval is given, acceptance is limited to pipe welding tasks which are within the limits set forth in the ASME "Boiler and Pressure Vessel Code," Section IX.

Renewal of a performance qualification is required when a welder has not used the specific process to weld either ferrous or nonferrous pressure piping components for a period of three months or more, or when there is a specific reason to question the welder's ability to make welds that meet the performance qualification requirements (ASME "Boiler and Pressure Vessel Code," Sec. IX).

Silver braze joints.—Silver brazes are recommended for joining copper-based materials and for joining dissimilar metals such as copper and stainless steel. The melting point must be greater than 1034 °F.

Bimetallic transition joints.—Transition joints are used to join dissimilar metals where flanged, screwed, or threaded connections are not practical. They are also used when fusion welding of two dissimilar metals forms interfaces that are deficient in mechanical strength and the ability to keep the system leak-tight. Transition joints consist of a bimetallic composite, a stainless steel, and a particular kind of aluminum bonded together by some proprietary process. Some of the types in use throughout the cryogenic industry are friction or inertia welded bond, roll-bonded joint, explosion-bonded joint, and braze-bonded joint. (See NSS/FP-1740.11.)

Soft solder joints.—Soft solder joints are **NOT** permissible in hydrogen piping systems. The soft solder is subject to embrittlement failures, has a low melting point, and will quickly fail in case of fire, thereby releasing hydrogen.

Bending and forming pipe.—Pipe may be bent to any radius that results in arc surfaces free of cracks and substantially free of buckles. Flattening of a bend, as measured by the difference between the maximum and minimum diameters at any cross section, should not exceed 8 percent of the nominal outside diameter for internal pressure and 3 percent for external pressure.

Piping components may be formed by any suitable hot or cold working method (swaging, lapping, or upsetting of pipe ends, extrusion of necks, etc.), provided that such processes result in formed surfaces that are uniform and free of cracks or other defects.

The various piping components shall be assembled, whether in a shop or in the field, so that the completely erected piping conforms to the specified requirements of the engineering design.

6.5.14 System Testing and Recertification

Plans for system testing and recertification must be developed during the system design process. See Chapter 7 of this Manual for requirements. Additional direction is provided in NMI 1710.3 and NHB 1700.6.

6.5.15 Contamination

Contamination must be prevented. The storage and piping systems, including system components, shall be designed and installed to allow for cleaning of the hydrogen system and for effective maintenance of a clean system. See appendix B of this chapter for more information.

Filters.—Filter placement should ensure effective collection of impurities in the system and accessibility for cleaning. The following are other guidelines for filter design:

- Filter elements should be made of noncalendered woven wire mesh.

- Sintered metal elements are not suitable because metal tends to spall and get into the system.

- As a general rule, the filter element should retain 100 percent of the particles greater than 0.0059 inches (150 micrometers) in diameter. Some systems, however, may require more stringent standards (NSS/FP–1740.11, Appendix).

Interconnected systems.—The passages in interconnected systems must be arranged so that cleaning or draining procedures can be developed to make sure that all piping, including dead-end passages and possible traps, is adequately cleaned.

Pressure levels: For interconnected systems operating at different pressure levels, adequate means shall be provided to prevent damage to the lower pressure system and its components. Spool pieces, nonstandard elbows, or tees are typically used to isolate the high- and low-pressure systems. Block and bleed valves and/or blind flanges may be required.

Protection from contamination by other fluids: Pressure-regulating valves, shutoff valves, and check valves do not adequately protect low-pressure systems connected to high-pressure systems. The low-pressure system must therefore have pressure-relief valves that are sized to handle the maximum high-pressure system flow. Discharge must be vented to a discharge or burnoff stack (see Sec. 6.5.16).

If the pressure differences in the systems cannot be managed by relief valves to prevent leakage and if the hydrogen system is not in use, the hydrogen supply shall be disconnected and capped. Other measures may also be necessary or useful in preventing contamination:

- Relief valves and burst disks are required for the protection of third piping systems supplied through valves from either the high- or low-pressure system.

- A double block and bleed valve design may help prevent system contamination by other fluids.

- Check valves shall not be used when bubble-free tightness is required; they can develop leaks during service. Two check valves in series have been found to be unreliable. In some cases, a single check valve has been more leak proof because the larger pressure drop closes the check valve more tightly.

- Leaking check valves in interconnected systems can contaminate bottled gases thereby jeopardizing the safety of laboratory operations. Suppliers of bottled gases specifically prohibit contaminating gases in their bottles. Check valves may, however, be used when system contamination is not important and where bottle pressures are not permitted to fall within 40 psig of the contaminating pressure. A safe pressure margin must be maintained.

- A check valve may be used in the vent line to limit air influx.

Explosion hazards: Explosion hazards in interconnected systems are caused by hydrogen leakage from one system into another. The design should recognize that leakage through valves is always a possibility; therefore

(a) Overpressurization safety systems shall be installed for protection

(b) The system shall be designed so that interconnected components can be separated and capped

Protection from contamination by oxygen, air, or nitrogen: Contamination can occur with interconnected systems (e.g., nitrogen purge system connected to hydrogen systems). **Check valves shall not be relied on to prevent contamination**. Localized concentrations of solid oxygen particles can become detonable in liquid hydrogen; therefore eliminate oxidants from the hydrogen system and observe the following precautions:

(a) Store liquid hydrogen under pressure (4 to 25 psig) to reduce the amount of external contaminants entering the system.

(b) Keep the pressurizing hydrogen gas at least 99.6 percent pure. Know the levels of impurities, especially oxygen, to ensure that the hydrogen gas is a satisfactory pressurant.

(c) Keep all gas and liquid hydrogen transfer and handling equipment clean, dry, and purged.

(d) Do not recirculate hydrogen if dangerous contamination cannot be prevented with reasonable certainty.

If contamination should occur, see Section 6.9.14 for decontamination procedures.

6.5.16 Safe Disposal of Hydrogen

Hydrogen shall be disposed of by atmospheric venting of unburned hydrogen or by using suitable burning systems.

Vent stacks.—Hydrogen systems and components must be equipped with venting systems that are satisfactory for normal operating requirements and that are protected against explosions. The vent stacks should be designed to keep air out of the stack and be placed to avoid contaminating the air intakes leading into nearby buildings.

Vent stack quantities: At Lewis Research Center, the guideline for the steady-state quantity of unburned hydrogen from a single roof vent should generally be limited to 0.25 pounds/second, released at least 15 feet above a roof peak. Multiple roof vents may be used at spacings of 15 feet and at locations across the prevailing wind. Significantly higher vent flows have safely and routinely been disposed of at Lewis. The Area Safety Committee may permit higher vent rates based on demonstrated safe experience or appropriate safety analysis.

At Plum Brook Station, the guideline for the steady-state quantity of unburned hydrogen is 0.5 pounds/second released from a single vent at least 15 feet above a roof peak.

Vent stack designs: See NASA Lewis drawings CF639138, CF639179, and CF303496 for typical 8-, 6-, and 4-inch vent designs.

In the preferred design, each flow system would have its own vent stack because interconnecting vent discharges to the same vent stack could overpressurize parts of the vent system. An inadequate design could effectively change the release pressure on all relief valves and rupture disks connected to the vent system, and overpressure could reverse buckle burst disks in other parts of the system.

High-pressure, high-capacity vent discharges and low-pressure vent discharges shall not be connected to the same vent stack unless there is sufficient vent capacity to avoid overpressurizing the weakest part of the system. The discharge from vacuum pumps shall be ducted to specifically dedicated vents.

The vent systems shall be designed to carry vented hydrogen to safe-release locations above the roof and support the excess thrust load caused by venting the liquid, vapor, or gas. Vents for hydrogen, however, shall not be interconnected with vents for other fluids.

Vent stack operations: Small quantities of hydrogen may be disposed of outdoors through vent stacks at suitable heights. A check valve or other suitable device should be provided in the vent stack near the atmospheric discharge to limit the backflow of air. The vent piping shall be pre-purged to ensure that a flammable mixture does not develop in the piping when hydrogen is introduced. Nitrogen gas may be used as a purge and blanketing gas when process temperatures are above −321 °F. For lower temperatures, helium gas should be used. Vent lines may need trace heating to prevent icing of relief devices.

Nonflare-designed hydrogen vent stacks may still occasionally ignite. Possible ignition sources include corona discharge and lightning. The design location of hydrogen vent stacks must take into consideration that all of these stacks may ignite and burn. A system and procedure shall be in place to terminate a hydrogen fire on all nonflare-designed vent stacks.

One cure, used at Kennedy Space Center and Plum Brook Station for nonflare standby vent stacks that often auto-ignited from atmospheric discharges, was to electrically isolate the top section (nominally 10 feet) of vent stack from the remainder of the system. Using a nonconducting gasket and bolt insulator sleeves at a flange joining the two sections allows the top section of the vent to electrically float at atmospheric potential and the lower section, at ground potential. An adjustable spark gap across the electrical isolation flange joint allows sparks to occur away from the venting hydrogen. (Bill Pack at Lewis has more detail.)

Explosion venting.—The severity of hydrogen-air tank explosions may be reduced by venting if the vent area is sufficiently large. Explosion vents shall not be connected to gaseous hydrogen vent systems.

In general, it is not possible to provide effective venting against an explosion in pipes or long, narrow tanks. See ANSI/NFPA 68, "Venting of Deflagration," for additional information.

Burnoff flare stacks.—Larger quantities of hydrogen that cannot be handled safely by roof vent systems are best disposed of in a burnoff system in which the liquid or the gas is piped to a remote area and burned with air. These systems shall have pilot ignition warning systems in case of flameout and a means for purging the vent line.

Diffusion flames are most frequently used in flare stack operations; that is, combustion air from the open atmosphere mixes with hydrogen beyond the vent stack discharge, not with the hydrogen within the stack. Although disposing of hydrogen by flaring is essentially safe, hazards related to flame stability, flame blowoff, and flame blowout do exist. The following list contains important safety rules for disposing of hydrogen by burning:

(a) The safe disposal of hydrogen through flare stacks requires suitable flows. Atmospheric wind may modify stable performance because the wind not only aids air entrainment but also may direct the flammable mixture laterally from the stack rather than to substantial heights above the facility.

(b) Malfunctions in flare stacks, such as fires and explosions, have generally occurred at low flows with air forced downward from the atmosphere. Stack discharge velocities should be from 20 to 30 percent of the sonic velocity. Where the flow is too low to support stable combustion, a continuous purge or a slight positive pressure should be provided.

(c) Liquid or gas in flared venting systems should be piped at least 200 feet (61 meters) from the work and storage areas and burned with air.

- Water pond burning (burn pond) may be used for rapid releases of large quantities as well as for relatively long releases. The hydrogen is dispersed through a submerged pipe manifold to evolve into the atmosphere, where it is ignited and burned. The water serves as a seal to prevent back mixing of air into the distribution manifold and pipeline and also provides some protection for the manifold from thermal radiation damage.

- Ignitable substances such as trees and grass shall be removed from the vicinity of overland flare stacks.

(e) Burnoff flare stacks shall be designed and operated so they do not present a hazard to low-flying aircraft.

Additional hydrogen burnoff information is provided in the Appendix of NSS/FP–1740.11.

Hydrogen in a trailer traveling on a highway should be disposed of by venting it **unburned** in a safe location, away from populated areas and high enough to increase dispersion.

<u>Altitude exhaust systems.</u>—Unburned hydrogen may be dumped into the altitude (vacuum) exhaust system only under certain conditions. Approval of the Area Safety Committee is required in all cases. Furthermore a special waiver from the Executive Safety Board is required before the following limits may be exceeded.

<u>Lean mixture operations</u>: It shall be permissible to introduce hydrogen-air mixture ratios **leaner** than 0.0068 by weight into the altitude exhaust system. (In calculating the hydrogen-air ratio, noncondensable inert gas that is added to the system may be considered as air.) This value is based on explosive limits and not on the lower limit of flammability. The 0.0068 ratio is about 25 percent of the lower explosive limit of hydrogen at standard pressure and temperature.

The preceding statement includes routine and emergency phases of altitude exhaust system operations including, but not limited to, hydrogen-rich experimental testing, engine blowout, failure to start, and hydrogen line failure within the exhaust system.

Rich mixture operations: Hydrogen-air mixture ratios richer than 0.0068 by weight may be introduced into an exhaust system provided that the entire system is capable of withstanding a detonation of the mixture. The system shall be capable of withstanding pressures 20 times the maximum system operating pressure; however, heads, baffles, elbows, and other types of obstructions must withstand 60 times the maximum system operating pressure.

Ultimate stress values may be used to calculate "design of system" pressures for rich mixtures because the pressure pulse is of such short duration.

Burnoff ignition torches.—With burnoff ignition torches, safe operation of hydrogen systems at sea level and within an altitude exhaust facility may be enhanced by controlled burning of free hydrogen before it can accumulate and detonate. This burnoff technique is effective at test cell pressures of greater than 4 psia.

6.5.17 Slush Hydrogen Systems

The primary considerations in the design of slush hydrogen systems are thermally protecting the fluid during handling and preventing air from intruding into the storage vessel.

Slush hydrogen systems shall be designed to operate so as to prevent air intrusion into the system (normally at 1.02 psia). Such systems must also be designed to handle possible system blockage and wear from the solid particles of hydrogen contained in the flow stream. The structural design materials suitable for liquid hydrogen service are also suitable for slush service.

6.6 MATERIALS

All structural materials shall be selected to provide safe performance with the least degradation of their mechanical properties.

6.6.1 Code Requirements

The materials for fixed-storage hydrogen containers shall be selected, and the containers designed, constructed, and tested, in accordance with the appropriate requirements of the ASME "Boiler and Pressure Vessel Code," Section VIII, "Pressure Vessels."

Materials specifications and thickness requirements for hydrogen system piping and tubing shall conform to the "Code for Pressure Piping, Chemical Plant and Petroleum Refinery Piping," ANSI/ASME B31.3. Piping or tubing for operating temperatures below −20 °F (−29.9 °C) shall be fabricated from materials that meet the impact test requirements of Chapter III of ANSI/ASME B31.3 when they are tested at the minimum operating temperature to which piping may be subjected in service.

6.6.2 Materials Selection

Selection of materials for liquid hydrogen use requires knowledge of the following:

(a) Hydrogen's unique properties and the effect of cryogenic temperatures on material behavior

(b) Specific requirements such as pressure, temperature, length of service, physical properties, fluid conditions, and critical performance requirements

(c) The mechanisms by which flaws can lead to failures

Typical materials.—Table 6.1 lists typical recommended materials and their applications in liquid and gaseous service systems.

Liquid hydrogen: Metallic construction materials for liquid hydrogen systems include aluminum, copper, Monel, Inconel, austenitic stainless steels (types 304, 304L, 308, 316, and 321), brass, and bronze. Nonmetallic materials include Dacron, Teflon, Kel-F, Mylar films, and nylon.

Kel-F (polytrifluorochloroethylene) or Teflon (polytetrafluoroethylene) can be used for the following:

- Valve seats (modified Teflon, although Fluorogreen is preferred)
- Soft coatings on metallic O-rings (to provide a more positive seal)
- Flat, thin gaskets for tongue-and-groove flanges, where the gasket is shrouded on four sides (All Teflon gaskets must be captured on all sides to prevent cold flow and subsequent leakage.)
- Spacers in the vacuum area between the liquid flow tube and the vacuum pipe
- Gland packing or seal (only if it is maintained near ambient temperatures as in an extended bonnet of a shutoff valve). When Teflon is cooled from ambient to cryogenic temperatures, the contraction or shrinkage allows leakage.

Gaseous hydrogen: Carbon steel meeting ANSI/ASME B31.3 standards may be used for gaseous hydrogen service above −20 °F.

Surface finish.—The compatibility of metastable austenitic stainless steels, such as type 304, with hydrogen is influenced by surface finish. Ductility losses and surface cracking occurred in machined samples tested to failure in 1000-psi (69-MPa) hydrogen. The extent of cracking can be minimized by either annealing or electropolishing to remove the surface layer produced by machining.

Welds.—Hydrogen system welds shall conform to the welding requirements included in ASME "Boiler and Pressure Vessel Code," Sections VIII and IX and ANSI/ASME B31.3, "Code for Pressure Piping."

In type 301 stainless steel and Inconel 718, a heat-effected weld zone frequently produces hard spots, residual stresses, and a microstructure conducive to embrittlement. Post-weld annealing may be required to restore a favorable microstructure.

Type 347 stainless steel cracks easily during welding, so appropriate welding precautions are required; it is an alloy that is not generally used.

Compatibility testing.—Materials that are not listed in this chapter may be suitable for hydrogen service. Alternate materials must be compatible with liquid and gaseous hydrogen under the conditions in which they are to be used and shall conform to the specifications approved by the responsible engineering design authority. The following selection criteria apply:

(a) The properties of materials used for design should be based on tests conducted under conditions that simulate service conditions.

(b) The designer should be careful in using values reported in the literature, since test and material conditions are highly variable. The allowable stresses for vessels or piping used for liquid and gaseous hydrogen shall be no greater than 50 percent of the minimum yield of the material at ambient temperatures.

(c) Because liquid hydrogen systems are subjected to cyclic loading, only materials with suitable fatigue life may be used. Materials considered for hydrogen systems should be evaluated under complex interactions of stress, pressure, temperature, and exposure conditions.

(d) Material compatibility with hydrogen should be tested by direct exposure of the materials. Testing should be done for tensile strength, fracture toughness, fatigue, bend, and stress rupture over a range of pressures and temperatures.

6.6.3 Hydrogen Embrittlement

Effect on mechanical properties.—Hydrogen service generally reduces the mechanical properties of structural materials. Such losses have been attributed to three independent primary factors: a critical, absorbed, localized hydrogen concentration; a critical stress intensity (crack length and applied or residual stress); and a susceptible path for hydrogen damage. Hydrogen effects on metals include the following:

(a) Environmental hydrogen embrittlement, present in metals and alloys plastically deformed in a high-pressure environment, which leads to increased surface cracks, losses in ductility, and decreases in fracture stress

(b) Internal hydrogen embrittlement, caused by absorbed hydrogen, which may cause failures in some metals with little or no warning

(c) Hydrogen reaction embrittlement, caused by absorbed hydrogen's reaction with the base metal, an alloy, or a contaminant, which typically results in very brittle hydrides that lower the metal's ductility

Considerations in design.—Mechanical property loss can be prevented by such measures as coatings, elimination of stress concentrations, additions of impurities to gas-phase hydrogen, oxidation treatments, grain size, specifications of inclusion morphology, and careful selection of alloys.

Available data are sometimes not sufficient to allow selection and application of any specific preventive measure, although the following recommendations can be made:

(a) Whenever practical, use aluminum alloys for hydrogen containment. Aluminum is one of the few metals with only minimal susceptibility to hydrogen attack.

(b) Use containers with thick walls of low-strength metals because they generally contain hydrogen more safely than containers fabricated from similar alloys treated for high strength.

(c) A metal or alloy exposed to cyclic stresses is almost certain to have lower resistance to fatigue if hydrogen is present; in the absence of data, always assume a fivefold increase in fatigue growth rates.

(d) Avoid the use of body-centered-cubic metals and alloys whenever practical.

(e) Do not use hydride-forming metals and alloys as structural materials for hydrogen service.

6.7 IGNITION SOURCES

6.7.1 Concept

Elimination of ignition sources is a second line of defense for safe operation with hydrogen. The general procedure is to eliminate all likely ignition sources.

Eliminating risks.—Hydrogen leaks and accumulations occur despite safeguards against them. The optimum protection against unsafe conditions is the elimination of all likely ignition sources near the hydrogen hazard areas. **However, escaped hydrogen is very easily ignited by unexpected means, and the presence of unknown ignition sources must be always suspected.** Therefore,

(a) Controls shall be established for limiting ignition sources in critical areas.

(b) Necessary ignition sources in hydrogen areas should be surrounded locally with inert gas and noncombustible heat sinks.

(c) Operating limits shall be established for all energized equipment, to minimize the temperature, energy, and duration of unavoidable ignition sources.

Maintaining acceptable safety risks.—If ignition sources are a required part of the hydrogen test apparatus, provisions shall be made to maintain acceptable safety risks during any resulting explosion or fire. Burnoff ignition torches may enhance safe test operations under these conditions by controlled burning of the hydrogen-air mixture when it first reaches a flammable level. The accumulation and detonation of larger hydrogen accumulations is then prevented. See Section 6.5.16 for more information.

6.7.2 Potential Ignition Sources

Ignition of hydrogen-air mixtures usually results in ordinary combustion or deflagration, and thus, hazards from overpressure and shrapnel are less than from detonations (refer to Sec. 6.4.2).

The autoignition temperature, the minimum temperature for self-sustained combustion, is 1065 °F (874 K) for a stoichiometric mixture of hydrogen and air. Compare this value with 481.4 °F (523 K) for kerosene and 438.2 °F (499 °K) for aviation fuel such as an octane. Although the autoignition temperature of hydrogen is higher than those for most hydrocarbons, hydrogen's lower ignition energy makes the ignition of hydrogen-air mixtures more likely. The minimum energy for spark ignition at atmospheric pressure is about 0.02 millijoules.

Electrical.—Electrical sparks are caused by sudden electrical discharges between objects having different electrical potentials (e.g., breaking electrical circuits or discharges of static electricity). Minimum values of electrical spark energy as a function of the volume percent of hydrogen are shown in Section 6.4.1.

Thermal.—Thermal ignition is caused by burning material or hot objects. Some examples are

(a) Sparks, which are caused by hard objects coming into forcible contact with each other—such as metal striking metal or stone, or stone striking stone (Sparks are particles of burning material that have been sheared off as a result of contact.)

(b) Objects at temperatures above 1065 °F (847 K), which will ignite hydrogen-air or hydrogen-oxygen mixtures at atmospheric pressure; substantially cooler objects (about 600 °F, 590 K) cause ignition under prolonged contact at less than atmospheric pressure

(c) Open flames and smoking, which can easily ignite hydrogen mixtures

6.7.3 Limiting Electrical Ignition Sources

Classification of hydrogen areas.—Areas where **flammable hydrogen mixtures are normally expected to occur** shall be classified as Class 1, Group B, Division 1, in accordance with the "National Electric Code" (NEC).

Areas where **hydrogen is stored, transferred, or used and where the hydrogen is normally contained** shall be classified as Class 1, Group B, Division 2, as a minimum. The "National Electric Code" (NFPA 70,) shall be consulted to determine if an area will be made safer by being classified as the more difficult Division 1 installation.

The Area Safety Committee may permit certain test cells where hydrogen is used to remain electrically unclassified if appropriate safety justification is presented. A rocket test cell firing into the open atmosphere might be an example. A waiver of the required Division 1 and 2 designations will be by special exception rather than as a rule.

Explosion-proof enclosures.—A Division 1 installation differs from a Division 2 installation mainly in its degree of isolation from the electrical ignition sources in the system. A Division 1 installation relies heavily on explosion-proof enclosures for its isolation; such an explosion-proof enclosure is **not** gas tight. Explosion-proof equipment is equipment that has been qualified by a testing laboratory as being "explosion proof" for a specific gas. It means that

(a) The enclosure is strong enough to contain the pressure produced by igniting a flammable mixture inside the enclosure, if code-required seals are properly used

(b) The joints and threads are tight enough and long enough to prevent issuance of any flames or any gases that would be hot enough to ignite a surrounding flammable mixture

Guidelines for installing and using explosion-proof equipment are given in NFPA 70, KSC–STD–E–0012, and ANSI/NFPA 496.

Equipment for hydrogen areas.—All electrical sources of ignition shall be prohibited in classified areas, including open electrical arcing devices and heaters or other equipment that operates at elevated temperatures. This means one should use approved explosion-proof equipment (Class 1, Group B, Division 1) or select non-arcing equipment approved for Division 2. Articles 500 and 501 of NFPA 70 cover equipment application and installation methods for these locations.

Intrinsically safe installations approved for hydrogen area service may be used if there is appropriate grounding, labeling, and wire separations in accordance with NFPA 70, Article 504, "Intrinsically Safe Systems," and ANSI/ISA RP 12.6 "Installation of Intrinsically Safe Systems for Hazardous (Classified) Locations."

Another alternative to using explosion-proof equipment is to locate the equipment in an enclosure that is purged and then maintained at higher than ambient pressure with air or an inert gas. An indication of positive pressure shall be provided. See "Purged Enclosures for Electrical Equipment," ANSI/NFPA 496.

Cost is minimized if electrical junction boxes are installed outside of the hazardous area. If systems are installed in the hazardous area, but not required during hazardous periods, they may be built with general-purpose equipment, provided that they be disconnected before the hazardous period begins. The conduits for such systems must be sealed in accordance with NEC requirements (NFPA 70) to contain hydrogen within the hazardous area and to exclude inert purge gases from control rooms and other occupied areas.

See Section 6.5.4 for electrical equipment selection

Classification of electric motors.—Electric motor classification rules and definitions are specified in NFPA 70, Article 501-8.

For Division 1 locations, a totally enclosed, fan-cooled motor can be used if an inert purge is used. Large electric motors are not generally manufactured in explosion-proof Division 1 configurations. However, electric motors of a non-arcing, nonsparking design (brushless, induction) are suitable for Division 2 locations if they meet the requirements of NFPA 70, Article 501-8.

In both Division 1 and 2 areas, surface temperatures of motors must not exceed 80 percent of the autoignition temperature of the surrounding gas. This means the motor case temperature must not exceed 867 °F for motors used in hydrogen service areas at ambient pressure. Monitoring of motor case temperature may be advisable under some conditions of use.

Grounding and bonding.—All transport, storage, and transfer system equipment and connections must be grounded. The offloading facility shall provide easily accessible grounding connections, and the connections shall be made before final operation.

"National Electric Code" Article 100 (NFPA 70) defines the term "grounded" and lists the sizes of grounding conductors. The minimum size used for grounding fixed equipment in Class 1 areas shall be no. 2 American wire gauge (49 CFR, Parts 170 to 180).

All of the metal components of a hydrogen system shall be electrically bonded and grounded in accordance with the "National Electric Code." This includes tanks, regulators, valves, pipes, vents, vaporizers, and receivers (mobile or stationary). Each flange should have bonding straps in addition to metal fasteners, which are primarily structural.

The resistance to ground shall be less than 10 ohms, and it shall be checked at least every 6 months to ensure this grounding is maintained. A facility record of these checks shall be maintained.

Portable electrical equipment.—Portable electrical and electronic equipment shall be properly electrically classified for use in a classified hydrogen area. Portable radios, pagers, and hydrogen detectors are typical pieces of equipment that must meet this criterion.

6.7.4 Other Ignition Sources

Lightning.—Lightning protection in the form of lightning rods, aerial cable, and ground rods shall be provided at all preparation, storage, and use areas. All equipment in buildings shall be interconnected and grounded to prevent induction of sparks between equipment during lightning strikes. This subject is developed further in NFPA 78, "Lightning Protection Code." The area considered to be protected by lightning rods or aerial cable is the area within 30° of either side of vertical.

Static.—Static and electrostatic charges may be generated in flowing gases that contain solid or liquid particles as well as in flowing liquids and gases that are pure.

Sparks.—Tests and experience indicate that in a liquid hydrogen atmosphere the energy required for ignition is so small **that even spark-proof tools can cause ignitions**. Therefore, all tools should be used with caution to prevent slipping, glancing blows, or dropping, all of which can cause sparks. Spark-proof and conductive floors, however, are **not** required.

Nylon clothing and certain kinds of electrically insulated shoes have generated large static electricity buildups and produced significant sparks.

Hot objects and flames.—The following rules will aid in preventing ignition by hot objects and flames:

(a) Clearly marked exclusion areas shall be established around hydrogen facilities, and smoking shall be prohibited inside these exclusion areas.

(b) Except as they occur normally during tests, flames and objects with temperatures above 80 percent of the hydrogen ignition temperature (871 °F; 739 K) shall be prohibited. Welding and cutting shall not be performed when hydrogen is present.

(c) Motor vehicles and equipment employing internal combustion engines shall be equipped with exhaust system spark arresters and hydrogen-safe carburetor flame arresters when they are operated in an established control area during hydrogen transfer.

(d) Flame arresters specifically designated for hydrogen applications shall be used to prevent open flames from contacting hydrogen-air atmospheres. A properly designed hydrogen flame arrester is very difficult to accomplish in practice because

- The small quenching distance of 0.024 inches (0.060 centimeters) for hydrogen makes it difficult to develop flame arresters and explosion-proof equipment that can successfully disrupt a deflagration or detonation originating within the equipment

- Flame arresters designed for hydrocarbon flames will not stop hydrogen flames, and flame arresters that are effective against hydrogen-air flames may not stop hydrogen-oxygen flames

(e) Vegetation and other combustibles shall not be within 25 feet (7.6 meters) of gaseous or liquid hydrogen systems, as required by ANSI/NFPA 50A and 50B.

6.8 DETECTION OF HYDROGEN LEAKS AND FIRE

6.8.1 Hydrogen Leak Detection Systems

General requirements of a reliable system.—A reliable hydrogen detection and monitoring system shall give warning when the worst allowable condition has been exceeded. This allowable condition must still be in the safe range, and the warning should indicate that a problem exists. Visual alarms should be designed into the system to indicate hazardous concentrations.

The system should also locate the source of a hydrogen leak within the facility during test operations. The goals for test facility hydrogen gas detection systems should be

(a) Detection of 1 ± 0.25 percent by volume of hydrogen in air

(b) Response time of 1 second at a concentration of 1 percent by volume

(c) Detection of 1 to 10 percent by volume of hydrogen in inert atmosphere

Portable detectors shall not be used as gas detectors for test installations that require remote location of personnel during the test period. Portable gas detectors are valuable for local leak detection.

Design and calibration requirements.—In the design of a detection system, all possible hydrogen leak sources to be monitored shall be listed and evaluated. Valid justification shall be presented for deciding not to monitor a possible leak source.

A means to ensure that any leaking hydrogen passes the detectors at the installation must be part of the system design and installation. Consideration should be given to using hoods to route any leakage across the detector, which should be positioned to indicate area detection rather than point detection. Hydrogen leaks at exposed liquid hydrogen valves and outside containers or at exposed vacuum-jacketed liquid hydrogen lines may be allowed to diffuse into the atmosphere.

The detection system design shall ensure that the system's expected response time is rapid enough to be compatible with the fire detection or auxiliary safety system.

To ensure acceptable performance, periodic maintenance and field-recalibration of detectors shall be conducted every 6 months. Facility records of these recalibrations shall be maintained.

Hydrogen detector locations and alarm levels.—The number and distribution of sampling points in hydrogen detection systems must be based on the possible rate of leakage, the amount of ventilation, and the size of the area. A single sampling point does not provide adequate sensing. Typical locations requiring detectors and the recommended performance requirements are presented here.

> NOTE: At STP, 1 percent by volume of hydrogen in air is 25 percent of the lower flammability limit.

Facility test and transfer areas: In the area around hydrogen facilities, a 1-percent by volume hydrogen concentration at any point 3.28 feet (1 meter) or greater from the hydrogen equipment shall generate an ambient pressure warning. A 2-percent by volume concentration shall generate a high-level alarm. The performance of these detectors depends on the location of the sensors and the leak and on the direction of the wind. The number of sensors must be adequate for the area.

In vacuum-jacketed equipment, detectors are not necessary bcause liquid hydrogen leaks may be detected through loss of vacuum, formation of frost, formation of solid air, or a decrease in outer wall temperature.

Enclosure exhaust ports: For exhaust vents from enclosures containing hydrogen piping and storage systems, detectors should be located in the vent stream at ambient pressure and within 3 feet of the vent port. Examples of such are vent ports from purged boxes containing hydrogen valves, and ventilation discharge ducts from enclosed force-ventilated test areas where hydrogen is used.

Although the Area Safety Committee may approve alternate detector locations, a detector shall warn of a 1-percent by volume gaseous hydrogen concentration in the purge exhaust from enclosed areas containing hydrogen systems. A 2-percent by volume gaseous hydrogen concentration, or higher, in the purge exhaust from enclosed areas would indicate a hydrogen leak and potential fire hazard within the enclosure. At this alarm level the hydrogen source shall be shut off.

Altitude (vacuum) chambers: Detectors in the altitude chamber shall generate an alarm if 1-percent by volume hydrogen concentration occurs when the chamber is not evacuated. A 4-percent by volume hydrogen concentration in the evacuated duct shall generate an alarm during altitude operation.

Leak detector accuracy and sensitivity cautions.—The catalytic combustion devices currently available can be affected by large concentrations of helium gas. Ionizing hand-held detectors cannot differentiate between gaseous helium and gaseous hydrogen, so a high helium concentration will give a high reading as if it were hydrogen. Furthermore, a nitrogen-rich environment can cause these detectors to give negative readings.

6.8.2 Fire Detectors

Hydrogen fires pose a special safety problem because the flames are essentially invisible. Therefore, thermal and optical sensors have been developed to detect burning hydrogen.

- Thermal fire detectors that can be classified as rate-of-temperature-rise detectors and overheat detectors are not subject to frequent failure. To cover a large area or volume, many thermal detectors are required and they must be located at or very near the site of a fire.

- Optical sensors for detecting hydrogen fires operate in two spectral regions, ultraviolet and infrared. In general, different sensors and optical components must be used in each region. Closed-circuit infrared and ultraviolet remote-viewing systems, equipped with appropriate filters, have been used successfully.

Fire detection systems should be installed in storage and use areas to warn whenever a worst-allowable condition is exceeded. The fire detectors should give a rapid and reliable indication of the existence, location, and size of a hydrogen fire.

Automatic shutdown systems, triggered by multiple fire detectors and activated quickly enough to prevent large-scale damage, should be considered. Connecting an automatic shutdown system to a fire-detecting system may not always be effective since alarms may be triggered by reflections from allowable fires (burn ponds and flare stacks) and sunlight.

6.9 STANDARD OPERATING PROCEDURES

6.9.1 Policy

Standard operating procedures (SOP's), with checklists as required, shall be developed for common operations. The SOP's should be set by individuals directly involved with hydrogen operations and shall be approved by the Area Safety Committee. These procedures should be reviewed periodically for observance and improvement.

Confined spaces.—Repairs, alterations, cleaning, or other operations in confined spaces in which hydrogen vapors or gases are likely to exist are not permitted until a detailed safety procedure is established. These procedures should

(a) Specify, as a minimum, the evacuation or purging requirements necessary to ensure safe entry and the maximum hydrogen concentration limits allowed (1 percent of the lower flammability limit in the confined space)

(b) Require that an acceptable gas sample be taken before personnel are allowed to enter

(c) Require that persons engaged in operations be advised of possible hazards

(d) Provide for emergency rescue training

(e) Ensure that at least one trained person is always available in case of emergency

For additional information, see "NASA Health Standard for Entry Into and Work in Confined Spaces," NHS/IH 1845.2.

Hydrogen vessels.—Before major work is performed on hydrogen vessels, they must be drained and purged of hydrogen. All pipelines leading to systems still containing hydrogen shall be disconnected, flanged, and tagged. The following should be done before work begins:

(a) De-energize electric power supply to equipment within the vessel.

(b) Purge tanks of flammable vapors, and test to ensure the effectiveness of the purging operation.

(c) For major repairs or modifications, warm and purge the vacuum annulus. Purging of vacuum jackets is a unique procedure that requires careful planning and execution.

6.9.2 Requirements for Personnel

Training shall familiarize personnel with the physical, chemical, and hazardous properties of hydrogen and with the nature of the facility's major process systems (i.e., loading and storage; purge gas piping; control, sampling, and analyzing; alarm and warning signals; ventilation; and fire and personnel protection (see Sec. 6.10)).

The buddy system of the appropriate level must be followed. Two "qualified operators" shall be present. This "qualified operator" policy applies to both hydrogen research test operations and hydrogen handling operations. However, no more than the minimum number of personnel necessary should be present in a hazard area (see Ch. 2).

6.9.3 Startup Examination and Inspection

Examination.—The Test Site Engineering Operations organization is responsible for ensuring that the following are accomplished before system startup:

(a) Before initial operations, all storage and piping installations and their components shall be inspected to ensure compliance with the material, fabrication, workmanship, assembly, and test requirements established by NASA. Hydrogen system examinations shall be performed in accordance with the ASME "Boiler and Pressure Vessel Code," Section V.

(b) The completion of all required examinations and testing shall be verified. Verifications should include, but not be limited to, certifications and records pertaining to materials, components, heat treatment, examination and testing, and qualification of welding operators and procedures.

(c) Materials must be identified for all piping and components used in fabrications and assemblies subjected to liquid hydrogen temperatures. No substitutions for the materials and components specified in the engineering design are permitted without written approval from the facility project engineer. During reassembly, cleanliness and dryness of all components shall be maintained.

Test records.—Records shall be made on each system and piping installation during system checkout testing. These records should include date of test; identification of system, component, and piping tested; test method (e.g., hydrostatic, pneumatic, or sensitive leak test); test fluid; test pressure; hold time at maximum test pressure; test temperature; locations, types, and causes of failures and leaks in components and welded joints; types of repair; test records; and the name of the responsible safety design engineer or operations engineer.

Test records shall be retained by the responsible operating organization and may need to be incorporated in the system configuration management system.

6.9.4 Signals and Identification

Safety signals.—Established uniform audible and visible safety signals are to be used at Lewis, and all personnel must know and obey them. The meanings of the signals shall be posted in all operation areas. These signals are specified in Chapter 19 of this Manual.

System identification.—The approved method of indicating the contents of a container or system is the **printed word**. Color codes are strictly secondary.

6.9.5 Checklists

Checklists are substantial aids to safe operations and therefore are required for all installations.

6.9.6 Allowable Hydrogen Leakage at Test Installations

Every reasonable effort should be made to eliminate leakage from installations where hydrogen is used. In practice, however, it is sometimes very difficult to completely eliminate leakage. Therefore, operations may be performed coincident with some leakage **if the test installation is entirely out-of-doors or in a well-ventilated expendable building**. Tolerable hydrogen leakage shall not exceed 25 percent of the lower explosive limit at a distance of 2 feet above the leakage source (no wind) and shall be permitted only when

(a) The source of leakage is known and the leakage is stable (e.g., leakage from a crack may be unstable because the crack might widen)

(b) Plentiful ventilation is provided

(c) The leakage is unconfined and free to diffuse rapidly

(d) Ignition sources are eliminated

(e) Gas detection means are employed as stated in Section 6.8

(f) Leakage is determined at test temperatures and pressures or by using helium in conjunction with a mass spectrometer and by converting the reading to the equivalent quantity of hydrogen

(g) The facility's responsible engineering manager gives written approval of the operation

6.9.7 Clean Systems

Systems, including their components, for storing and piping liquid and gaseous hydrogen shall be appropriately cleaned for service, thereby ensuring the removal of contaminants and avoiding mechanical malfunctions, system failures, fires, or explosions. Effective cleaning will remove greases, oils, and other organic materials as well as particles of scale, rust, dirt, weld spatter, and weld flux.

The cleaning of liquid hydrogen systems is a specialized service that requires well-trained, responsible individuals to properly carry out the necessary procedures. Note the following guidelines:

(a) Some systems may require disassembly for suitable cleaning. Components that could be damaged during cleaning should be removed and cleaned separately.

(b) The compatibility of cleaning agents with all system construction materials must be definitely established. Cleaning methods include steam or hot water cleaning; mechanical descaling; vapor, solvent, or detergent degreasing; acid cleaning; and purging.

(c) Clean flexible hoses and pipe sections should be sealed and marked to indicate certified cleanliness. The ends should be closed with metal caps and then covered with a clean plastic bag or sheet and, where required, sealed with a tamper-proof seal tape.

(d) Systems should be rechecked periodically for cleanliness; the schedule should be determined by the facility engineers. Accumulations of wear debris and frozen contaminants are possible.

(e) Cleaning operations, agents, and their effects on construction materials are described briefly in appendix B of this chapter.

6.9.8 Purging

Before a hydrogen system or vessel is loaded, it must be made inert. This may be accomplished by a vacuum purge, a positive pressure purge, or a flowing gas purge to ensure complete removal of any contaminant gases. These gases, when trapped in a liquid hydrogen system, solidify and introduce the possibility of contamination, fire, or explosion.

Vacuum purge.—Vacuum purging is the most satisfactory method of making a system inert since it requires fewer operations and ensures the elimination of air or nitrogen pockets. The system is vented to the atmosphere, evacuated to a relatively low pressure, repressurized with an inert gas to a positive pressure, and again re-evacuated. Before purging the system, the operator must be sure that the container or system will not collapse when the vacuum is applied.

Recommended steps for a vacuum purge are as follows:

(a) Evacuate the system to below 10 torr (1.333 kilopascals).

(b) Perform a pressure rise rate test under static conditions and ensure that the system is tight by observing the rate of pressure rise within the system. (A 1-torr/minute (133-pascals/minute) rise for a 5-minute period indicates good vacuum holding ability.)

(c) Backfill with nitrogen or helium to atmospheric pressure.

(d) Re-evacuate to 10 torr (1.333 kilopascals).

Two or more cycles of steps (c) and (d) may be required to achieve a contaminate concentration that is low enough (nominally 0.1 percent by volume). A theoretical determination of concentration can be found by multiplying the ratios of the absolute pressures for each purge cycle.

Positive pressure purge.—A positive pressure purge requires alternate pressurizing and venting of the system to progressively dilute air until a safe environment is obtained.

(a) Air in the system is diluted with an inert gas to a positive pressure within the working pressure range of the vessel. (Helium must be used for liquid hydrogen system purges; nitrogen will freeze at liquid hydrogen temperatures.) The mixture is then displaced by venting to the atmosphere.

(b) The system is repressurized to the positive pressure, and the mixture is again vented to the atmosphere. A positive pressure must be maintained in the receiver during these procedures to prevent the backflow of air.

(c) Following a check to ensure the system oxygen level is below 0.1 percent by volume, liquid or gaseous hydrogen may be introduced into the container.

It may be necessary to repeat these steps to obtain a safe hydrogen environment. A theoretical determination of contaminant gas concentrations can be found by multiplying the ratios of the absolute pressures for each purge cycle.

The system is now ready for hydrogen, and the vacuum may be broken with hydrogen gas.

Flowing gas purge.—A flowing gas purge is the least likely method of ensuring a positively purged system. It requires the use of an inert gas flowing into one part of the system and out of another part of the system. Helium must be used for liquid hydrogen systems; nitrogen or helium may be used for gaseous hydrogen systems.

Considerations in a flowing gas purge are volume to be purged, gas flow rate, and purge duration. Turbulent flow or a sufficiently high flow rate must be achieved to thoroughly purge all parts of the system. This method should be used only for short lines.

System purge sample.—A newly purged system should be sampled to ensure it is safe for loading hydrogen. Normally, this requires the oxygen level to be below 0.1 percent by volume. Since nitrogen can contaminate a liquid hydrogen system by condensing and freezing at liquid hydrogen temperatures, nitrogen concentrations below 0.1 percent by volume are recommended.

6.9.9 Gaseous Hydrogen Tube Trailers and Cylinders

Gaseous hydrogen tube trailers.—Specific equipment and procedures are required for gaseous hydrogen tube trailers.

Equipment requirements: All Lewis-owned gaseous hydrogen tube trailers shall be fitted with remotely operated transfer shutoff valves of a Lewis standardized design and configuration. Only inert gas or dry air shall be used to operate these remote shutoff valves.

Transfer lines (trailer to facility) may be made of corrugated stainless steel, rubber, or Teflon hose, with the proper pressure rating, inside an external braid of stainless steel. Proper restraining cables and anchoring are required. A stainless steel tube with proper pressure rating may also be used. Forming the tube into a large loop provides for some flexibility in the connection.

Operational procedures: Specific operational procedures to connect, start up, and shut down Lewis gaseous hydrogen tube trailer systems are found in appendix A of this chapter.

Gaseous hydrogen cylinders.—To prevent the infiltration of air into gas cylinders, the cylinder pressures should not be allowed to fall below 150 psig.

Mandatory procedures: Specific operational procedures for the safe use of gaseous hydrogen cylinders are found in the Compressed Gas Association publication CGA Pamphlet G-5, Sections 4 and 5. CGA Pamphlet G-5 is hereby adopted as a part of this chapter.

Safety rules: These rules apply to all portable gas cylinders.

(a) Do not transport cylinders unless the valve is covered with a protective bonnet.

(b) Never handle cylinders roughly.

(c) Secure cylinders in an upright position with a chain, cable, or strap.

(d) Store cylinders where they are not subjected to physical damage and where they are protected from direct summer sunlight.

(e) Do not use leaky or damaged cylinders; mark them "defective" and notify the Safety Assurance Office.

(f) Never alter, repair, change, or disassemble a valve or safety disk on a cylinder.

(g) Use proper regulators on all cylinders. Tag regulators to indicate use.

(h) Do not use a wrench to open a cylinder valve. If it can't be opened by hand, tag it as a bad valve and return it to "Gas Handling."

(i) Remove cylinders to a safe storage area when they are not being used.

6.9.10 Storage, Transfer, and Test Operations

A facility's Standard Operating Procedures shall include safe general operating procedures for the storage, transfer, and test areas (29 CFR 1910.103). In addition, the facility shall provide good illumination, lightning protection, alarm systems, and gas detection and sampling systems. (The hydrogen detection equipment should be calibrated for short response times and detection of 25 percent of the lower flammability limit.)

To limit spill quantities, transfer operations shall be monitored whenever practical and provisions should be made for a programmed automatic shutdown in case the loading or unloading system fails. Furthermore, to protect the unloading area in case of a leak or spill, no liquid hydrogen transfer shall begin unless there is a positive shut-off capability in the supply vehicle system.

As part of the transfer procedures at Cleveland, the Lewis Fire Department or safety representative should be notified of the liquid hydrogen offloading location and time. At Plum Brook, Plant Protection should be notified. The responsible manager shall verify that a pretest briefing has been conducted, that approved procedures are used, that emergency escape routes are clear, and that the operational area is clean and free from combustible materials and ignition sources.

Contractor unloading procedures, along with vehicle schematics and descriptions of the piping systems that interact with the NASA facility, must be provided to ensure performance of necessary precautions and procedures during and after unloading operations. As an additional safeguard, checklists shall be made of the operations performed by the supplier and user of the liquid hydrogen.

6.9.11 Cold-Shock Conditioning

All vessels and lines to be used for cryogenic service should be cold-shocked before final leak testing. Cold-shocking verifies the integrity of the system for use at cryogenic temperatures. It is especially important that the expansion and contraction from ambient to cryogenic cycling not impose excessive stresses on any component.

Only those liquid hydrogen systems determined to be strong enough to carry the extra nitrogen weight may be cold-shocked with liquid nitrogen.

Components may be function tested while immersed in liquid nitrogen, but fluid systems should be conditioned with liquid nitrogen (preferably) or hydrogen and function tested at operating conditions. After the system has been purged, vented, and warmed to ambient temperature, all connections and threaded fittings should be retorqued.

The entire system should be inspected for evidence of cracking, distortion, or other anomaly, with special attention given to welds. After repairs, cold-shock tests may be repeated prior to the final pressure test.

6.9.12 Liquid Hydrogen Tank Cooldown

When a warm liquid hydrogen tank is being filled, the tank vent should be connected to a stack to remove hydrogen vapors from the work area. The liquid flow shall be throttled carefully to satisfactorily handle the flashoff through the vent system and to limit stress development due to excessive cooldown. Typical cooldown hydrogen vapor flows are 0.5 to 1.0 pound/second (0.23 to 0.46 kilograms/second). Note: If a warm dewar needs to be filled, the commercial supplier often can deliver large amounts of cold gaseous hydrogen to the NASA dewar before liquid hydrogen is added, thereby helping to reduce dewar cooldown stress.

The filling system must be controlled so that the maximum liquid flow rate into the vessel is less than the tank vent system venting capacity. High vent flow rates can result in vent fires caused by static discharge. They can also result in excessive pressure increases that cause the safety valves to open or the safety disk to rupture. Tank pressures shall not exceed tank design working pressure during any routine operation.

6.9.13 Optional Liquid Nitrogen Precool

An optional method of preparing a warm vessel or system to receive liquid hydrogen uses liquid nitrogen for precooling. The cooling process evaporates large amounts of the cooling liquid, so the vessel must be determined strong enough to carry the added load of nitrogen before this method is attempted. The following procedure is to be used:

(a) Evacuate the vessel or system to approximately 10 torr (1.333 kilopascals). If this vacuum cannot be tolerated, a warm, inert gas pressure purge should be carefully planned as an alternate procedure.

(b) Introduce the liquid nitrogen into the vessel or system, taking care to prevent air migration, which will cause contamination.

(c) Allow ample time to obtain all of the cooling possible from the liquid and the cold gas. Drain off the remaining liquid nitrogen.

(d) Remove the nitrogen atmosphere by purging the vessel with helium. Make sure all of the nitrogen is removed from the vessel; this is very difficult to accomplish. (Vacuum or pressure pulse purging can be used to remove gaseous nitrogen.)

(e) Admit liquid hydrogen into the vessel or system.

6.9.14 Liquid Hydrogen Systems

The equipment and techniques employed in the storage, transfer, and use of liquid hydrogen are determined by the requirements of the user. Procedures shall be approved by the Area Safety Committee.

General procedures.—The procedures for operating transfer and propellant system equipment will be determined by local designs and construction, the type of equipment, and the procedures prescribed by either the local engineering operations group or the equipment manufacturer. All personnel should be completely and thoroughly instructed before operating the equipment, and all valves, pumps, switches, and such, should be identified and tagged. A written operating procedure shall be used at each operational site.

When all filling and transfer connections have been properly made, all inlet and vent valves should be set and checked before the transfer operation is started. Local piping designs will determine the details of the foregoing operation. Inspections for possible contamination and for operating conditions of the equipment are recommended after extended use and after periods of extended shutdown.

Composition acceptance tests.—Requirements for liquid hydrogen composition, sampling methods, and quality performance testing are listed in specification MIL–P–27201B and ASTM F310–70. Composition acceptance tests should be performed on the deliverable hydrogen in accordance with this specification before it leaves the filling site.

Liquid hydrogen transfers.—For safe transfer of liquid hydrogen, note the following:

(a) Dewars shall be connected to electrical ground, inspected generally for leaks and mechanical defects, and checked for pressure and vacuum. The connections shall be cleaned and purged. (Contamination must be avoided.)

(b) Surfaces should be monitored for condensed water or frost, since these may indicate leaks. Minor frost at bayonet connections is quite common and expected. Cold spots on vacuum jacketed piping at the annulus spacers are also common.

(c) All transfers must be made in closed systems. Liquid hydrogen shall not be transferred into an open-mouthed dewar or be allowed to come into contact with air, for it can become contaminated with solid air. All hydrogen transfers should be made against enough backpressure to prevent air ingestion.

(d) Liquid and gaseous hydrogen should not be transferred if there is an electrical storm or a fire near the facility.

(e) Procedures to prevent overloading liquid hydrogen trailers and storage tanks must be followed. Overloading reduces the ullage space and may result in liquid hydrogen leakage during transportation (for trailers); excessive thermal cycling may cause the relief valves to become inoperable.

Beware: A major cause of leaks and spills in loading and unloading areas has been the accidental removal of mobile dewars or gas tube trailers before a transfer hose is disconnected.

Ullage requirements for liquid hydrogen dewars.—Ullage or vapor space must be maintained above the liquid hydrogen surface for safety purposes. (Filling into this space constitutes unsafe overfilling.) The design capacity for this equipment includes an excess volume normally 10 percent above the rated full capacity as shown on the level gauge. For example, a full 13,000-gallon dewar contains 13,000 gallons of liquid hydrogen and has a 1,300-gallon vapor space.

Retention of this ullage serves to avoid possible hydrostatic rupture of the vessel, since the vapor in the ullage is readily compressible whereas the liquid is not. It provides an ebullition surface to enable de-entrainment of the liquid from the vent stream and helps prevent freeze-up and consequent malfunction of the overpressure protective devices. Since changes in temperature affect the density of liquid hydrogen, available ullage varies. DOT regulations allow pressure to increase from 1 atmosphere to 17 psig in transit. This represents an ullage volume increase of more than 5 percent.

In summary, without adequate ullage, it is possible to get liquid into the vent piping during venting operations or through sloshing effects during transit. This impairs the operation of these systems and creates hazardous conditions.

System leak repair.—No leaks shall be repaired until all pressure in the appropriate systems has been bled. All tools and fittings should be cleaned appropriately before use.

Contamination.—Contamination must be prevented. Liquid hydrogen can be contaminated by liquefied or solidified gases when it is exposed to air or other gases with a higher boiling point. Containers suspected of being contaminated must be removed from service immediately and must be tagged or otherwise identified as unfit for service. Arrangements with the group responsible for that container shall be made for special handling of the container.

Condensation of contaminants during loading: During loading of cryogenic hydrogen, water or any other condensable vapor may condense inside the system. In large systems, even contaminant levels measured in parts per million can produce a sizable frozen mass that could impede flow or system function.

Before a cryogenic system is loaded, all air, water, and condensable vapors shall be purged or evacuated from the system. Experimentation and sample analysis may be required to define the degree of purge or the number of evacuation cycles required.

Removing a liquid hydrogen vessel from service: Any liquid remaining in tanks containing liquid hydrogen or cold hydrogen vapor shall be removed through the liquid transfer hose to a liquid disposal system or shall be allowed to boil off through the tank hydrogen pressure buildup coil. Venting must take place through an approved hydrogen vent stack.

Purging a liquid hydrogen tank after the liquid is removed requires the use of gaseous helium or gaseous nitrogen. The instrumentation, calibrating and operating valves and lines, self-pressurization valves (hydrogen pressure buildup coil), and rupture disk bypass valves should be open during purging and venting.

During the final venting the appropriate trailer valves shall be opened slightly to provide purge gas flow through the trailer connections and lines. A sample of the vented gas shall be taken from the trailer vent and from the empty try-cock valve to verify a hydrogen concentration of 1 percent or less by volume. A warmup period should follow.

Dewar decontamination: Tanks and dewars should be decontaminated (derimed) periodically by draining the contents and letting the product container warm up to permit removal of all contaminants. The warmup period shall be determined from the service history.

Contamination often occurs in roadable dewars, which are frequently filled and emptied. Large, fixed dewars generally do not require frequent decontamination unless they inadvertently become contaminated. The interval then depends on the degree of contamination, and engineering judgment must be used. This decision shall be made by the responsible managers.

To ensure decontamination, the container should be vacuum purged and vacuum static checked to 10 torr (1.333 kilopascals), if it is strong enough to withstand a vacuum. If the dewar is not strong enough, a warming or pressure purge will be necessary, and dew point and gas analyses should follow.

6.9.15 Removal of Dewars and Gas Trailers From Test Facilities

Dewars and gas trailers should be disconnected from the test equipment after rig operation and moved away from the test facility as soon as practical. However, in controlled areas where large dewars are used and disconnection may constitute a hazard, the dewars may remain connected between periods of research operation at the discretion of the Area Safety Committee. Gaseous hydrogen trailers, isolated from the system manifold, may also be left on site with the approval of the Area Safety Committee. When dewars and tube trailers are moved, the peak traffic hours should be avoided.

6.9.16 Substitution of Dewars

Substitutions are **not** permitted unless approved by the cognizant Area Safety Committee and the responsible engineering managers. With interchange of equipment, purging must be complete and contents must be accurately marked on the dewar. Note that many liquid hydrogen dewars are not structurally capable of handling the heavier liquid nitrogen or oxygen.

6.9.17 Slush Hydrogen

Procedures for handling slush hydrogen include those for gaseous and liquid hydrogen. However, additional procedures are required for slush hydrogen. Section 6.4.6 highlights the added hazards of slush operations.

Preventing and monitoring air intrusion.—System designs and operational procedures shall be developed and shall always be followed to eliminate the possibility of air intrusion into slush hydrogen systems. Operating slush hydrogen systems shall be monitored continuously for the intrusion of air.

Periodic system warmup.—Slush hydrogen systems should periodically be warmed to above the boiling points of nitrogen and oxygen (above 200 °R), and the residual gas should be analyzed. If nitrogen and oxygen are present, air has probably intruded and the system should be cleaned of any entrapped air.

The "NASA Hydrogen Safety Standard" (NSS/FP–1740.11) provides an extensive discussion of operations with slush hydrogen.

6.10 PROTECTION OF PERSONNEL AND EQUIPMENT

The best single investment in safety is trained personnel. Full consideration for the safety of personnel at and near hydrogen facilities must start at the earliest planning and design stages.

Training should familiarize personnel with the physical, chemical, and hazardous properties of liquid and gaseous hydrogen and with the nature of the major processing systems in the facility. It should also provide operators with practice in handling hydrogen as well as in handling emergency spills and fires.

Operators shall be kept up to date on changes in facility operations and safety procedures.

6.10.1 Protective Clothing

All personnel who handle liquid hydrogen or who may be exposed to cryogenic vapors shall have eye and body protection. Any unprotected parts of the body must not be allowed to touch uninsulated pipes or vessels that contain liquid hydrogen, because the cold will cause the flesh to stick and tear. Any clothing that is splashed or becomes soaked with hydrogen vapors should be aired out.

Face shields shall be required when the system is being operated under pressure, when lines or components are being connected or disconnected, and when the system is being vented, unless the vent system releases gases away from all personnel.

Proper gloves (e.g., leather) shall be worn when handling anything that comes in contact with cryogenic liquids or vapors. These gloves should fit loosely and come off easily.

Adequate foot protection should be provided; open or porous shoes are not permitted. Trousers must be kept outside the boots or work shoes.

6.10.2 First Aid for Cryogen-Induced Injuries

Exposure to cryogenic gases/liquids.—Cryogenic burns result when tissue comes into contact with cold gases, liquid, or their containers. The result may be merely skin chilling or true tissue freezing. Commonly, only small areas are involved and the injury is to the outer layers of the skin.

Small quantities of cryogenic material may evaporate from the skin before actual freezing occurs; this injury typically produces a red area on the skin. More significant injury is caused by true freezing, the formation of crystals within and around the tissue cells. Frozen tissue always assumes a yellowish-white color, which persists until thawing occurs.

Steps to prevent and emergently care for cryogen-induced injuries must be incorporated into safety standards and training programs for operations and emergency response. Personnel shall be knowledgeable about the risks of injury from cryogens.

Treatment of frozen body tissue.—Treatment of truly frozen tissue requires medical supervision since incorrect first aid practices invariably aggravate the injury. In the field it is safest to do nothing other than cover the involved area, if possible, and transport the injured person to a medical facility.

> NOTE: **Attempts to administer first aid for this condition will often be harmful. Here are some important don'ts:**

(a) Don't remove frozen gloves, shoes, or clothing except in a slow, careful manner (skin may be pulled off inadvertently). Unremoved clothing can easily be put into a warm water bath.

(b) Don't massage the affected part.

(c) Don't expose the affected part to temperatures higher than 112 °F (such as a heater or a fire). This superimposes a burn and gravely damages already injured tissues.

(d) Don't expose the affected part to temperatures lower than 100 °F.

(e) Don't apply snow or ice.

(f) Don't use safety showers, eyewash fountains, or other sources of water, because the temperature will almost certainly be incorrect therapeutically and will aggravate the injury.

(g) Don't apply ointments.

Although safety showers may be provided, they are exclusively for nonmedical purposes such as extinguishing fires or flushing acid. Safety showers should be tagged, "Not to be used for treatment of cryogen burns."

6.10.3 Access to Hazardous Areas

Test-cell entry forbidden.—Test cells and buildings with combustible hydrogen mixtures in the atmosphere shall **NOT** be entered under any conditions. Furthermore, no personnel may enter a test cell when liquid hydrogen or propellant gaseous hydrogen is flowing in the cell.

Test-cell entry conditions.—Every entry into an operating test cell must be considered dangerous. After conditions within the cell have been determined to be safe, only authorized personnel shall be granted entry **and then only** if the project operating engineer and the personnel who are entering determine such entry is necessary. The appropriate buddy system shall be employed, and entry shall be limited to essential personnel.

Monitoring personnel in cells.—The presence of personnel in an operating test cell shall be known to personnel outside the test cell. In-cell personnel shall be monitored continuously by others outside the cell, either by direct sight or closed circuit TV or by the two-man buddy system with periodic calls back to the control room.

Warning personnel of hazards.—Personnel must be warned of the presence of combustible mixtures or low oxygen concentrations. Automatic warning systems shall operate both an audible and a visible alarm. Warning alarms shall be designed so that they are **not** ignition sources themselves.

Work in confined hydrogen areas.—Unless a detailed safety procedure is established, work is not permitted in confined spaces in which hydrogen gas could exist. See Chapter 16 of this Manual.

6.10.4 Protective Shelters and Control Rooms

Structures close to the test facilities, which would normally house personnel during a test, shall be designed to adequately protect the occupants if the test facility should explode. The design shall be in accordance with the guidelines in Section 6.5, considering the following:

(a) Particular attention shall be paid to the ventilation or source of air for shelters that may, in case of emergency, be enveloped in hydrogen gas or the products of combustion.

(b) Inert gases shall not be piped into tightly sealed shelters if there is a possibility of accidental release, which could result in suffocation from lack of oxygen. Likewise, purged electrical gear and conduits shall be sealed from personnel shelters.

(c) Hydrogen shall not be piped into shelters or control rooms.

(d) In hydrogen test areas, barricades are often needed to shield personnel, dewars, and adjoining areas from blast waves and/or fragments. Barricades may also be needed to isolate liquid hydrogen storage areas that are too close to public property.

6.10.5 Safeguards in Inert Environments

Asphyxiation is a safety concern for personnel entering vessels containing inert environments. Acute asphyxia, as from breathing 100-percent inert gases, produces immediate unconsciousness without warning; it happens so quickly that individuals cannot help or protect themselves. Workers may fall as if struck down by a blow on the head and will die in a few minutes if not resuscitated.

To prevent asphyxiation, the contents of a vessel's atmosphere shall be checked before any personnel enter it. Any person entering a vessel shall wear a harness-type safety belt with a lifeline attached. The line must be tended by a watcher positioned outside the vessel at a point where the watcher can be in constant communication with the worker throughout the time the worker is in the vessel. In addition, the worker shall wear a supplied-air respirator if asphyxiation could occur (see Chapter 15 for proper respirator equipment).

Personnel shall never enter an enclosure or vessel which may contain unsafe quantities of hydrogen or any other inert or toxic gas. Only the Executive Safety Board can waive this requirement.

6.11 BLAST EFFECTS AND SEPARATION DISTANCES

6.11.1 Quantity-Distance Concept

Quantity-distances are based on the concept that the effects of fire, explosion, and detonation can be reduced to tolerable levels if the source of hazard is kept far enough from people and facilities. Tests, analyses, and experience are employed to determine the relationship between the effects of an accident and the quantity of material involved in the accident. From a knowledge of the tolerance levels of people and structures, safe distances are determined. These distances are based entirely on the estimated damage that could result from an incident, without considering probabilities or frequency of occurrence (CPIA–394–VOL–3). Baker et al. (1975) and 29 CFR 1910.95 present information on methods for predicting yields and blast behavior of propellant explosions. Baker et al. (1975 and 1978) and KHB 1710.2 present information on fragmentation effects from explosions.

6.11.2 Quantity-Distance Policy

The quantity-distances are intended as a basic guide in choosing sites for hydrogen operations; they are based on the total quantity of propellants at a particular site and are intended to minimize damage to facilities and to protect personnel from injury.

A hazard analysis shall be performed for each facility system or subsystem. This analysis shall take into account the physical state of the hydrogen propellant (liquid or gas), whether oxidants are present in the system, and the quantities of propellants that could be involved.

The recommended separation distances shall be based on the references listed in the following section. Recommended distances may be impossible to achieve, but proper design can sometimes guarantee that only part of the total propellant supply or only one of the propellants will be involved in an accident. If Area Safety Committees are satisfied that such positive safeguards exist, they may approve lesser distances.

6.11.3 Quantity-Distances for Liquid and Slush Hydrogen

Quantity-distances have been established for two different situations: (1) storage of liquid or slush hydrogen, in which case the main hazards are pressure rupture, fragmentation, and gas-phase burning of hydrogen in air; and (2) the use of liquid hydrogen in propulsion test systems together with liquid oxidizers, in which case the main hazards are rapid combustion or detonation of liquid hydrogen-oxidizer mixtures.

DOD quantity-distances.—The DOD classifies bulk liquid hydrogen storage as a Group III hazard. The Department of Defense manual 6055.9, "Ammunition and Explosive Safety Standards," provides quantity-distance tables for liquid propellants. See tables 6.2 to 6.5, preceding the appendixes of this chapter.

NOTE: These tables apply only to liquid and slush propellants.

Table 6.2 gives not only the recommended quantity-distances between bulk liquid hydrogen storage and compatible propellants but also those between both unprotected and protected inhabited buildings, public traffic routes, and incompatible propellants. These distances provide reasonable protection from fragments of tanks or equipment that are expected to be thrown about should a vapor-phase explosion occur.

NFPA quantity-distances for bulk liquid hydrogen storage.—An alternate quantity-distance separation can be used, contingent on Area Safety Committee approval, only for bulk liquid hydrogen storage as specified in ANSI/NFPA 50B, "Liquefied Hydrogen Systems at Consumer Sites." The stringent requirements of NFPA 50B, Chapter 4, "Design of Liquefied Hydrogen Systems," and either CGA Pamphlet S–1.2, for mobile vessels, or S-1.3, for stationary vessels, must also be met to use these distances. These values are predicated on the installation of a CGA S–1.2- or 1.3-sized emergency vent system that will prevent a storage vessel rupture even when the vessel is surrounded by fire.

The NFPA quantity-distances do NOT apply to slush hydrogen.

Liquid hydrogen use with oxidizers.—Where liquid hydrogen is used in conjunction with liquid oxidizers such as oxygen or fluorine, as in rocket engine static test operations, the quantity-distances are based on blast hazards. The total weight of propellants (fuel plus oxidizer) that could be involved in accidental release must be related to an equivalent amount of TNT or similar highly explosive material that would produce the same blast wave overpressure.

Tables 6.3 to 6.5 should be used to determine the blast hazard separation distances. For example, a given total quantity of liquid hydrogen plus liquid oxidizer, accidentally released, can be expected to produce a blast wave characteristic of some smaller amount of a highly explosive material. To determine the equivalent amount of explosive, multiply the combined total weight of propellants by the explosive equivalent factor, and then use the results to determine the separation distance.

Distances to inhabited buildings and to public traffic routes for various quantities of equivalent propellant mixes are given in table 6.4; and intraline distances, the distances to be maintained between similar propellant combinations within the facility complex, are given in table 6.5.

6.11.4 Mandated Quantity-Distances for Gaseous Hydrogen

The installation and location of gaseous hydrogen systems, both fixed and tube trailer, shall conform to the requirements in ANSI/NFPA 50A, which shall be considered an integral part of this chapter.

Required quantity-distances are based on the total volume of hydrogen involved. The location of a system shall be in the order of preference indicated in ANSI/NFPA 50A.

6.11.5 Fragmentation

Analytical predictions of fragment velocity distributions, fragmentation patterns, and lifting and rocketing fragment free-flight ranges are contained in the "NASA Basic Safety Manual," (NHB 1700.1, Volume 1–A); "Occupational Noise Exposure," (29 CFR 1910.95); and "Assembly and Analysis of Fragmentation Data for Liquid Propellant Vessels" (Baker et al. 1974). These references also describe methods for determining the effects of fragments on concrete and steel walls.

6.11.6 Need For Barricades

Barricades are often needed in hydrogen test areas to shield personnel, dewars, and adjoining test areas from fragments. For maximum protection, barricades should be placed adjacent to the fragment source.

NOTE: A common misconception is that barricades significantly reduce the overpressures experienced at extended distances. Barricades serve only to stop fragments; after the blast wave passes the barricade, it re-forms with almost full strength.

Barricades may also be needed to isolate liquid hydrogen storage areas close to public property. In addition, they are needed to protect uncontrolled areas from the possible rupture and fragmentation of a storage dewar and to protect the storage dewars against vandalism.

For additional design information on barricades, see Section 6.5.9. Also see "Workbook for Estimating Effects of Accidental Explosions in Propellant Ground Handling and Transport Systems" (Baker et al. 1978) and "Hazards of Chemical Rockets and Propellants," (CPIA-394-VOL-1).

6.12 EMERGENCY PROCEDURES

6.12.1 Basic Guidelines

If an uncontrolled leak, fire, or other emergency occurs, notify the Fire Department at Lewis or Fire and Accident at Plum Brook (as appropriate) by calling 911. Specific actions are listed here for such emergencies as leaks and spills, overpressurization, and transportation emergencies.

Leaks and spills.—Fire is the principal danger from a spill or leak. To help reduce the danger of fire, make sure that storage, transfer, and use areas are well ventilated and that ignition sources are avoided.

If a spill occurs, do not allow personnel or vehicles into the area affected by the spill. Completely rope off the area and post signs. If rope or signs are not available, station a person upwind to warn personnel.

Liquid: If a liquid leaks or spills from the piping of a vessel or pumping system, remotely shut off the source of supply. After the equipment or piping has been thoroughly vented and purged, the system can be disassembled and the leak repaired.

Gas: Gas leaks are more frequently heard than seen. As soon as leaks are detected, immediately stop operations, shut off the source of the supply, and relieve the line (or system) of any pressure. Resume operations only after the repairs are completed.

Accumulated combustible gas mixture.—If there is an accumulation of combustible gas in a test cell or area, do the following:

(a) Evacuate the area. Personnel shall stay out of areas where there are combustible gases.

(b) Shut off the gas and ventilate the area.

(c) Assess the situation and, if necessary, actuate the emergency shutdown switch. All hydrogen test rigs using electrically actuated valves should have an emergency shutdown safety switch that drives system valves with known safe positions to their safest positions.

(d) **Do not actuate electrical or other devices having questionable nonsparking characteristics.** Portable telephones and radios usually fall in this category. Metal dampers, sashes, doors, and such may create sparks when opened.

(e) Notify the Fire Department at Lewis or Fire and Accident at Plum Brook by calling 911.

6.12.2 Controlling Leaks

Controllable leaks are relatively small leaks that do not result in a significant spill before block, shutoff, and relief valves can be enabled. Uncontrollable leaks are large and may cause major spills. In such circumstances, do the following:

(a) Take actions to ensure the safety of personnel (i.e., take precautions against fires and explosions).

(b) Notify the safety and fire departments by calling 911 at Lewis or at Plum Brook.

(c) Evacuate the area within 500 feet (152 meters) of the spill source.

(d) Cool down adjacent equipment to protect it from possible fire.

6.12.3 Hydrogen Gas Leaks From Cylinders

Only properly trained technicians shall be permitted to work on leaking hydrogen gas cylinders, and they shall use only approved solutions to test for leaks (e.g., Leak-tek). If a cylinder safety device leaks, no attempt should be made to tighten the safety device cap while the cylinder is under pressure. Follow this procedure:

(a) Empty the contents of the cylinder in a safe location.

(b) Remove the cap and examine the condition of the threads.

(c) Correct the damage.

(d) Pressurize and leak-test.

6.12.4 Slush Hydrogen Emergencies

The most significant hazard associated with slush hydrogen is the intrusion of air into the hydrogen storage vessel. The emergency procedures that apply to liquid hydrogen also apply for slush hydrogen use (see Sec. 6.12.1). Special additional emergency procedures for slush hydrogen air intrusion problems are detailed in NSS/FP–1740.11.

6.12.5 Transportation Emergencies

Tanker hazards.—Hazards can occur in transporting liquid hydrogen by highway tanker. Some of the likely places and causes are

(a) During tanker preparation, testing, and filling at the producer's site

(b) During delivery of cargo at the user's site or preparation of the tanker for return

(c) Because of vehicle malfunction, road conditions, traffic situations, or driver error

(d) Because of cargo leakage en route

(e) Because of vehicle mishaps resulting in cargo leakage or spillage

Emergency procedures.—**In the event of a transportation emergency, the first concern shall be to prevent death or injury**; therefore, try to get the dewar off the road, preferably to an open location if possible. Shut off the tractor trailer electrical system, post warning lights and signs, and keep people at least 500 feet (152 meters) away.

For vent fires or other minor fires, attempt to shut off the hydrogen supply, but only if this is feasible and can be done safely. Do not try to put out a hydrogen fire while it is still being supplied with hydrogen. If a water hose is available, use it to keep metal parts cool until the fire burns itself out. A fire extinguisher should be used to put out engine, tire, or electrical fires that are not fed by hydrogen.

If there is no fire, fog may be visible near a cold leak. Stop or minimize the leak if it can be done safely. Remove all ignition sources. Since a flammable mixture may exist when fog is visible, and sometimes beyond the visible cloud, do not deliberately flare hydrogen leaks.

Communications.—A tractor trailer transporting liquid hydrogen should be equipped with a radiotelephone to allow the driver to communicate immediately about any difficulty. If physically able, the driver should remain in the general vicinity of the vehicle at all times. The first priority is reduction of any risk to the lives of emergency personnel and bystanders. The following are important:

(a) Drivers should be trained to take prompt protective measures and to be aware of the aid they can obtain from the Chemical Transportation Emergency Center (CHEMTREC) and other emergency information systems.

(b) The toll free CHEMTREC telephone number is 800-424-9300.

(c) Other emergency information sources include the Dow Chemical USA Distribution Emergency Response System (telephone 517-634-4400) and the Union Carbide Corporation Hazardous Emergency Leak Procedure (HELP), which provides information 24 hours a day. The HELP telephone number is 304-744-3487.

Major accidents.—If a major accident makes it impossible to move the dewar off the road, post warnings and keep people away. Notify authorities first, then notify home base. Keep **ALL** people, including firefighters, at a safe distance; an explosion could occur.

If there is a large hydrogen fire in which the source of hydrogen cannot be shut off, do not allow firefighters to extinguish it. Have them use water streams from a safe distance to cool the container and surrounding equipment, and to put out secondary fires.

If there has been major damage to the vacuum shell or vent system, pressure may build up and cause the liquid hydrogen container to rupture explosively. Vacate the area and keep people at least 500 feet (152 meters) away. If the surface of the inner vessel or insulation is exposed, do not apply water; this acts as a heat source to the much colder hydrogen and aggravates the boiloff.

If frost spots appear on the outer jacket, liquid hydrogen may be contacting the jacket, which is usually made of carbon steel. This metal becomes brittle when cold and should not be struck or shocked, since it could break.

Overturned trailers.—If an accident occurs in which the trailer is overturned,

(a) Request the aid of the local police and fire departments

(b) Seek assistance from anyone to stop traffic and evacuate the area. Do not use flares to alert or control traffic; traffic should be detoured.

(c) **Do not perform any procedures on an overturned trailer unless they are well thought out before action is taken. This activity carries a very high risk.**

- In the overturned trailer, the ullage space and the venting and pressure-relief devices are exposed to the liquid. It is possible, however, to reduce the tank pressure by venting gas through lines normally used for liquid flow.

- The detailed liquid hydrogen tanker piping schematics indicate the lines and valves that allow such an operation.

(d) Vent the trailer, if necessary, but only after consultation with the home office.

Emergency venting.—DOT regulations require the driver to avoid unnecessary delays during transportation. The pressure in the sealed dewar must be monitored. If it shows signs of approaching the relief valve setting, the truck must be driven to a remote and safe location and the pressure must be reduced through the manual blowdown valve. Observe the rate of pressure rise, and plan manual venting operations for the daylight hours, if possible.

Repeated emergency venting during transport is unusual; however, if it is necessary, do not proceed on the established route, but drive the tanker to a safe, open off-the-road area that is clear of power lines, buildings, and people. In choosing an area, consider the wind direction so that vented gas will be carried away safely.

Liquid hydrogen trailers are equipped with at least two safety valves. If the road safety valve relieves, pull off the road, and then either

(a) Let the road safety valve relieve until it reseats, or

(b) Use the tank operating vent valve to reduce the pressure.

Regardless of which method is used, the tank should be vented as soon as possible to less than 25 psia (172 kilopascals). Before returning to the highway, reconnect the tank to the road safety valve. The information required for selecting either of the two safety valves should be on the trailer schematic located on the trailer operating cabinet door.

Faulty relief valves.—Make no attempt to repair a relief valve leak while the valve is exposed to the tank pressure, because such procedures are hazardous. Special methods have been developed for replacing relief valves when the trailers are loaded with liquid hydrogen; however, such operations should be performed under the direction of the company safety engineering office.

Rupture disk failure.—Procedures for handling rupture disk failure depend on the type of disk on the trailer.

Single disk: Many trailers have one rupture disk whose replacement requires that specific detailed procedures be carried out in a remote area, that firefighting equipment be present, and that protective clothing be worn. A procedure is provided in the Appendix of NSS/FP–1740.11.

Dual rupture disk assembly: If the trailer is equipped with a dual rupture disk assembly, the driver must be familiar with the type of three-way valve used to switch to the other rupture disk. The gas flow should stop when the switch to the new disk is completed. The ruptured disk should be replaced as soon as possible.

6.12.6 Assistance in Emergencies

Responsible test site and safety personnel shall monitor hydrogen operations to ensure that all safety precautions are taken during transfer, loading, testing, and disposal operations. In any emergency, assistance should be available from knowledgeable safety-trained personnel, including plant security, fire department, and site personnel.

Site personnel trained in handling specific mishaps and accidents should be assigned definite tasks to perform in an emergency. These tasks should be assigned by the test site senior operations engineer.

6.12.7 Firefighting Techniques

Catastrophic results from fires can be prevented by training personnel to

(a) **Prevent the fire from spreading and let it burn until the hydrogen is consumed** (Use water to keep adjacent equipment cool, not to arrest the fire.)

(b) **Be aware that if the fire is extinguished without stopping the hydrogen flow, an explosive mixture may form, causing a more serious hazard than the fire itself**

(c) Exercise extreme caution in fighting fires involving hydrogen

In the event of a test facility fire, the fire fighting should be under the joint direction of the senior fire fighting officer and the senior test site engineer.

Liquid hydrogen fire scenario.—The following are descriptions of the initial and final phases of a liquid hydrogen fire.

Initial phase of fire: When a storage tank ruptures, flames will occupy the volume around the ruptured tank. Spills of a few hundred gallons may cause a flash hot-gas ball about 50 feet (15.12 meters) in radius. Wind may change the shape to an ellipsoid almost entirely downwind of the rupture. Flame temperature will be approximately 3800 °F (2370 K). Large amounts of liquid hydrogen will flash into vapor.

The hot-gas ball will radiate, but more slowly than in gasoline-air fires. Radiation effects on adjacent vessels and lines should not be severe, especially if they have reflective painting or surfaces.

Detonation of hydrogen-air mixtures in unconfined spaces is unlikely. However, the rapid burning of the initial cloud produces pressure waves that are sometimes strong enough to damage structures and injure personnel.

Final phase of fire: Because hydrogen fires are invisible and radiate less than ordinary fires, their presence is not as easily detected. The invisible flame may be many feet long and shift quickly with the slightest breeze. Therefore, **personnel should wear protective clothing when fighting hydrogen fires.**

The only sure way of handling a hydrogen fire is to let it burn under control until the hydrogen flow can be stopped. If the hydrogen fire is extinguished and the hydrogen flow is not stopped, a hazardous combustible mixture begins to form immediately. It is very possible for the mixture to ignite with an explosion, causing more damage and restarting the fire.

The block or isolation valves located close to the hydrogen container should be closed by remote operations from a safe distance outside the local hazard area.

Although the hydrogen fire should not be extinguished until the hydrogen flow can be stopped, water sprays should be used to extinguish any secondary fire and to keep the fire from spreading.

- The hydrogen-containing equipment should be kept cool with water sprays to decrease the rate of hydrogen leakage and to prevent further heat damage. **However, if the inner surface is exposed, water should not be applied.**

- Some pressure-relief devices have frozen shut from water spray during liquid hydrogen fire fighting activities. Great caution must be exercised in using water since a frozen relief device can lead to vessel rupture.

Remotely controlled water spray equipment, if it has been installed, should be used instead of hoses to cool equipment and to reduce the spread of the fire. If it is necessary to use hoses, those using them should stay behind protective structures.

It is permissible to use carbon dioxide in the presence of hydrogen fires.

Gaseous hydrogen fire scenario.—Gaseous hydrogen fires are not generally extinguished until the supply of hydrogen has been shut off, because of the danger of reignition or explosion. Hydrogen systems should be designed to allow the gas flow to be stopped. In a fire, water should be sprayed on adjacent equipment to cool it. Fog and solid stream nozzles are the most adaptable in controlling fires.

In dealing with hydrogen cylinder fires, proceed as follows:

(a) Do not try to put out a fire unless the cylinder is out in the open or in a well-ventilated area free of combustibles and ignition sources. Extreme care should be taken in attempting to extinguish the fire. The process may create a mixture of air and escaping hydrogen that, if reignited, may explode.

(b) Do not attempt to remove the burning cylinder but keep it and any surrounding cylinders and combustibles cool by spraying them with water.

(c) If a group of cylinders is burning, it is extremely important that the persons fighting the fire be at as great a distance from the fire as practicable and be protected against the possibility of flying debris. The efforts of firefighters in such instances should be divided between keeping the cylinders cool and preventing adjacent equipment and buildings from catching fire.

6.12.8 Protection from Exposure to Fire

Fires can damage objects by heat fluxes transmitted by radiation and convection. Radiation is a significant component of heat flux in hydrogen fires.

Water molecules are responsible for much of the infrared radiation from the hydrogen flame; therefore, atmospheric water vapor is very effective in absorbing this radiation. For example, a 1-percent concentration of water vapor in the atmosphere (corresponding to a relative humidity of about 43 percent at ambient temperature) will reduce the radiation flux at least two orders of magnitude at a distance of 328 feet (100 meters). Water spray/mist is an effective means for attenuating radiation from a hydrogen flame.

Comparisons of hydrogen fires with hydrocarbon fires show that, although smoke inhalation danger is lower with hydrogen fires, it remains a major cause of injuries and deaths in a hydrogen fire.

Safe limits for thermal-radiation-flux exposure levels for personnel and equipment cover a wide range and are listed in the Appendix of NSS/FP–1740.11.

6.13 TRANSPORTATION OF HYDROGEN

Safety of personnel and facilities while hydrogen is being transported requires adherence to accepted standards and guidelines as well as mandatory compliance with existing regulatory codes.

6.13.1 Codes and Regulations

Various industrial and government organizations have published standards and guidelines for facility construction and for safe procedures to be followed in the various phases of producing, handling, transporting, and using of cryogenic fluids.

Pertinent published guidelines have been adapted by regulatory bodies such as the Department of Transportation (DOT), which includes the Federal Aviation Administration (FAA), the U.S. Coast Guard, and the Office of Hazardous Materials Transportation. Department of Transportation regulations, Title 49, Code of Federal Regulations, Parts 170 to 180 designate the rule-making and enforcement bodies of the DOT.

A list of Federal regulations that pertain to the transportation of cryogenic fuels and compressed gases (fuels), as well as sources for nonmandatory safety guidelines and standards, and pertinent publications from a number of safety groups are listed in the Appendix of NSS/FP–1740.11.

Transport dewars are to be marked in accordance with DOT regulations with both of the following legends: "FLAMMABLE GAS" and "LIQUID (or GAS) HYDROGEN," as appropriate.

6.13.2 Loading Area Requirements

Liquid hydrogen is delivered to Lewis facilities in tanker trailers. The contracts for supplying hydrogen state that personnel involved in the handling, transportation, and storage of hydrogen must be given appropriate safety training.

The safety operating procedures included in the safety documents at Lewis will be rigidly followed to protect personnel. Emergency procedures shall be detailed in the standard operating procedures of the applicable operating organization. Other requirements are as follows:

(a) No flame-producing devices shall be located within the control area. Spark-producing and electrical equipment that is within 25 feet (7.6 meters) of the operation and is not hazard-proof shall be turned off and locked out. All tools used shall be in accordance with established safety procedures.

(b) The transfer and control areas must remain clear of personnel not directly involved in the operation. Loading and transfer of liquid or gaseous hydrogen should not begin during an electrical storm and, if under way, should be discontinued if a storm comes within 5 miles (8.05 kilometers) of the operation.

(c) In liquid hydrogen trailer transfer

- There shall be no smoking or open flames within 150 feet (45 meters) of the loading or unloading of a liquid hydrogen trailer.

- The tractor ignition switch and light circuit must be turned off during loading and unloading operations.

- When the tractor is parked, the trailer wheel chocks must be in place, the brakes set, and the static ground attached.

- Before the trailer is used, all external or associated systems should be inspected (e.g., for cold spots on vacuum jackets or visible leakage).

(d) If a leak develops, the transfer must be stopped and the leak repaired. If a hydrogen fire occurs, the hydrogen sources must be closed as quickly as possible.

(e) Before any type of maintenance is performed, the system shall be depressurized and all liquid hydrogen lines disconnected, drained, vented, and purged; the operations area inspected; and the security of all systems verified.

(f) The atmosphere must be free of hydrogen in the air before motor vehicles are permitted to operate within the control transfer area. At a hydrogen alarm level of 50 percent of the lower flammability limit, vehicles shall be shut off, and personnel shall immediately leave the area of high hydrogen concentration.

(g) All transport dewar inlets and outlets, except safety relief devices, should be marked to designate whether they are covered by vapor or liquid when the tank is filled to the maximum permitted level. This is a DOT marking requirement.

(h) Each cargo tank must be protected by a primary system of one or more spring-loaded pressure-relief valves and by a secondary system of one or more rupture disks arranged to discharge upward and unobstructed to the outside of the protective housing. The rated capacity of each pressure-relief device must be set in accordance with Compressed Gas Association Pamphlet S–1.2.

6.13.3 Mandatory Transport Regulations

The following is a sample of mandatory regulations for safe tractor trailer transportation of liquid hydrogen:

(a) Drivers shall be required to successfully complete the training and certification programs provided by the supplier. These programs should include instructions about the nature of loading and the procedures to be taken in an emergency.

(b) Two drivers are to be assigned when normal driving time exceeds 10 hours between the point of origin and the destination or between driver relay points.

(c) The maximum allowable travel time, the pressure used to determine the marked rated holding time (MRHT), and the appropriate filling density must be marked on the right side of the cargo tank near the front, in accordance with 49 CFR, Parts 170 to 180. The one-way travel time is derived from the MRHT of the cargo tank for liquid hydrogen at the pressure and filling density (in percent) marked on the tank.

(d) The trailer shall be equipped with a spring-loaded, fail-safe emergency brake system.

(e) The trailer shall be equipped with a dry chemical fire extinguisher. The rating should not be less than Underwriter's Laboratory and NFPA Codes of 10 BC; some special permits require a rating of 20 BC.

(f) Each tanker must have an installed brake interlock switching system that ties the tank venting system to the brake system of the trailer. The objective of such a control is to permit venting of the tanker when it is in a controlled park position. For the trailer to be moved without venting, the brake switch position must be moved from park to drive.

6.14 ADOPTED REGULATIONS

This chapter is based on the best information available in 1991. It draws heavily on material from the "NASA Hydrogen Safety Standard" (NSS/FP–1740.11), compiled by Paul Ordin, and from the 1968 "Hydrogen Safety Manual," authored by Frank Belles. Much additional information is taken from NFPA and CGA standards. Experience gained over the past 30 years with hydrogen systems at Lewis Research Center also contributed much to the development of the new safety chapter.

This chapter was compiled by Wayne A. Thomas, Lewis aerospace engineer. It represents the consensus of a 12-member Technical Contributing and Review Committee of Lewis engineers and technicians (see appendix C), who are considered experts on hydrogen safety, design, fabrication, and use. Grateful acknowledgment is given for their support in providing technical monitoring of this standard, for the constructive reviews provided by other experienced members of the Lewis staff, and for the support of technical writer Wilma Graham.

The following documents or portions thereof are referenced within this chapter as mandated regulations and shall be considered as part of the requirements of this chapter; however, whenever there is a conflict between information presented in a reference and information contained in this chapter, the chapter information shall govern.

Copies of these adopted regulations may be obtained from the Safety Section of the Lewis Library:

NMI 1710.3, "Safety Program for Pressure Vessels and Pressurized Systems."

ANSI/NFPA 50A, "Gaseous Hydrogen Systems at Consumer Sites."

ANSI/NFPA 50B, "Liquefied Hydrogen Systems at Consumer Sites."

CGA Pamphlet G-5, "Hydrogen."

The "NASA Hydrogen Safety Standard," NSS/FP–1740.11, provides an outstanding source of additional practical safety, design, and handling information on the use of hydrogen in gas, liquid, and slush forms. Mr. Paul Ordin (deceased), along with a large group of other contributors, compiled this extensive collection of hydrogen information. Many useful references are also provided. Much valuable guideline information used in this chapter was extracted from the original drafts of NSS/FP–1740.11. Hydrogen system operations or design engineers are strongly encouraged to obtain a copy of this publication.

TABLE 6.1.—RECOMMENDED MATERIALS FOR HYDROGEN SYSTEMS

[From NSS/FP–1740.11, Appendix; and Belles 1968.]

Component	Liquid hydrogen service	Gaseous hydrogen service
Valves	Forged 304 stainless steel or brass body with extended bonnet	Commercial practice
Fittings	Stainless steel bayonet type for vacuum jackets	Commercial practice
O-rings	Stainless steel (or Kel-F)	Commercial practice
Gaskets	Soft aluminum, lead, or annealed copper between serrated flanges; Kel-F, Teflon, Flourogold	Encapsulated asbestos, Mylar, lead, annealed copper, Teflon
Hoses	Flexible 316 stainless steel	High pressure
Rupture disk assembly	Type 304 or 304L stainless steel flanges	Forged steel flanges
Piping	Type 304 or 304L stainless steel	Uncoated wrought steel or any 300-series stainless steel
Dewars	Type 304 or 304L stainless steel	Not applicable
Tapes	Teflon	Teflon
Thread compound	DC-4	Commercial practice
Lubricant for O-rings	Dupont Krytox 240AC, Fluoramics OXY-8, Dow Corning FS-3452, Dow Corning DC-33, Bray Oil Braycote 601, General Electric Versilube, Houghton Cosmolube 5100	Lubricants for liquid service suitable for gaseous environment

TABLE 6.2.—SEPARATION DISTANCES FOR LIQUID HYDROGEN STORAGE

[Extracted from DOD 6055.9 and CPIA-394-VOL-3.]

Quantity of liquid hydrogen, lb	Distance to inhabited buildings, public traffic routes, and other incompatible[a] storage, ft		Distance to other liquid hydrogen or compatible[a] propellant storage, ft
	Unprotected[b]	Protected[c,d]	
100	600	80	30
200		100	35
300		110	40
400		120	45
500		130	50
600		135	50
700	600	140	55
800		145	55
900		150	60
1,000		150	60
2,000		175	65
3,000		190	70
4,000	600	200	75
5,000		210	80
6,000		220	80
7,000		225	85
8,000		230	85
9,000		235	90
10,000	600	240	90
15,000	1,200	260	95
20,000		275	100
25,000		285	105
30,000		295	110
35,000		300	110
40,000	1,200	310	115
45,000		315	120
50,000		320	120
60,000		330	125
70,000		340	130
80,000		350	130
90,000	1,200	360	135
100,000	1,200	365	135
125,000	1,800	380	140
200,000		415	155
300,000		440	165
400,000		465	175
500,000	1,800	485	180
600,000		500	185
700,000		515	190
800,000		530	195
900,000		540	200
1,000,000		550	205

[a]Appendix D of CPIA-394-VOL-3 provides information on other compatible and incompatible propellants and is adopted as part of this table.

[b]Distance provides reasonable protection from fragments of tanks or equipment that are expected to be thrown about in a vapor-phase explosion.

[c]Terrain, solid concrete walls, barricades, nets, or other physical means provide protection from fragments.

[d]Recommended distances are inhabited building distances (2/cal/cm on 1-percent water vapor curve).

TABLE 6.3.—EXPLOSIVE EQUIVALENT FACTORS[a] FOR LIQUID PROPELLANTS

[From table D-3, CPIA-394-VOL-3.]

Liquid propellant combination	Explosive equivalent factor,[b] E
H_2 and O_2	0.60
H_2 and RP-1 and O_2	[c].70
H_2 and F_2	.05

[a]These values are valid only for liquid-liquid propellant combinations (DOD 6055.9).
[b]From static test stands.
[c]Value represents sum of E for H_2 and O_2 (0.60) and E for RP-1 and O_2 (0.10).

TABLE 6.4.—SEPARATION DISTANCES FOR LIQUID HYDROGEN-LIQUID OXYGEN PROPELLANT COMBINATIONS

[Extracted from DOD 6055.9, table 9–1.]

Weight of explosive equivalent W,[a] lb	Distance[b,c,d,e] from potential explosion site, ft		Weight of explosive equivalent W,[a] lb	Distance[b,c,d,e] from potential explosion site, ft	
	Barricaded inhabited buildings	Barricaded public traffic routes		Barricaded inhabited buildings	Barricaded public traffic routes
1	40	24	4,000	635	380
2	50	30	5,000	685	410
5	69	40	6,000	730	440
10	87	52	7,000	770	460
20	110	65	8,000	800	480
30	125	75	9,000	835	500
40	140	83	10,000	865	520
50	150	89	20,000	1,090	655
100	190	115	30,000	1,250	745
200	235	140	40,000	1,370	820
300	270	160	50,000	1,475	885
400	295	175	60,000	1,565	940
500	320	190	70,000	1,650	990
600	340	205	80,000	1,725	1,035
700	355	215	90,000	1,795	1,075
800	375	225	100,000	1,855	1,115
900	390	235	200,000	2,770	1,660
1,000	400	240	300,000	3,345	2,005
1,500	460	275	400,000	3,685	2,210
2,000	505	305	500,000	3,970	2,380
3,000	580	350			

[a]W = sum of weights (in pounds) of liquid propellants multiplied by explosive equivalent factor; for example, $W = (W_{LH_2} + W_{LOX})E$.

[b]See Sections 6.5.9 and 6.11.16 for barricade information. For unbarricaded buildings, multiply the distances in table 6.4 by two.

[c]For quantities of propellant up to but not over equivalent of 100 pounds (45 kilograms) of explosives, distance shall be determined on individual basis by controlling NASA center. All personnel and facilities, whether involved in operation or not, shall be protected adequately by proper operating procedures, equipment design, shielding, barricading, or other suitable means.

[d]Studies have shown that for small quantities of explosive mixtures and near-field distances, fragment hazard is greater than blast hazard; however, for large quantities and far-field distances, blast becomes the principal hazard since air resistance prevents fragments from traveling very far. This changeover occurs at 30,000 pounds (~13,608 kilograms).

[e]If an explosive mixture is mixed within a confined space such as a rocket motor or building that would surely produce fragments, the DOD Explosives Safety Board recommends that these values be replaced with 600 feet (183 meters) for explosive equivalents ≤100 pounds (45 kilograms) and 1250 feet (366 meters) for equivalents of 101 to 30,000 pounds (45.8 to 13,608 kilograms).

TABLE 6.5.—INTRALINE[a] DISTANCES FOR LIQUID HYDROGEN-LIQUID OXYGEN PROPELLANT COMBINATIONS

[Extracted from DOD 6055.9, table 9–3. This table is not applicable when blast fragments and debris are completely confined as in certain test firing barricades.]

Weight of explosive equivalent, W, lb	Intraline distance,[b,c] D, ft	
	Barricaded	Unbarricaded
50	30	60
100	40	80
200	50	100
300	60	120
400	65	130
500	70	140
600	75	150
700	80	160
800	85	170
900	85	175
1,000	90	180
1,500	105	210
2,000	115	230
3,000	130	260
4,000	145	290
5,000	155	310
6,000	165	330
7,000	170	340
8,000	180	360
9,000	185	370
10,000	195	390
20,000	245	390
30,000	280	560
40,000	310	620
50,000	330	660
60,000	350	700
70,000	370	740
80,000	390	780
90,000	405	810
100,000	420	840
200,000	525	1,055
300,000	600	1,200
400,000	665	1,330
500,000	715	1,430
600,000	760	1,520
700,000	800	1,600
800,000	835	1,670
900,000	870	1,740
1,000,000	900	1,800

[a]Per DOD 6055.9, the minimum distance necessary to limit direct propagation of an explosion by the blast wave from one run or storage complex containing both oxidizers and fuels to another similar complex. Indirect or delayed propagation may result from thrown fragments, debris, or firebrands. Personnel injuries of a serious nature due to fragments, debris, and firebrands are likely.

[b]Distances are based on blast effect of propellant combinations.

[c]For less than 50 lb (23 kg), shorter distances (determined by $D = 9W^{1/3}$ for barricaded and $D = 18W^{1/3}$ for unbarricaded) may be used when structures, blast mats, and line can completely contain fragments and debris.

6.15 APPENDIX A—RECOMMENDED PROCEDURES FOR GASEOUS HYDROGEN TUBE TRAILERS

6.15.1 Operational Requirements

Only qualified operators are to perform transfers.

While in storage or transport, a properly secured tube trailer shall have all valves in the closed position and the tailpieces and sample port capped.

A two-man buddy system shall always be in place in accordance with LMI 1704.1.

CAUTION: Eliminate all potential ignition sources from the area.

6.15.2 Tube Trailer Fill

(a) Ground the trailer at the connector on the bumper.

(b) Secure trailer doors with the latches provided.

(c) Chock/block trailer wheels. Also place at the front of the trailer a cone or sign indicating that the trailer is connected to the manifold.

(d) Put up the required barricades and signs.

(e) Open the gauge isolation valve to ensure that the supply manifold has maintained pressure and is leak-free. (If the manifold has leaked to atmospheric pressure, cease operations and contact the cryogenic maintenance COTR for proper evaluation and repair.)

(f) Leak-check the trailer manifold piping (use Leak-tek and/or hand-held analyzer).

(g) Connect an approved transfer hose to the fill tailpiece and supply-side fitting (maintain cleanliness of caps).

(h) Secure the transfer hose restraining cables to the eyelets provided.

(i) Open all tube isolation valves.

(j) Vacuum evacuate or purge the transfer line as specified in the area where the fill or cascade is being accomplished. Leak-check the hose connections prior to completing the purge.

(k) After the transfer hose has been purged and checked, stand clear of the transfer hose and slowly open the trailer-mounted manual fill valve.

(l) Require personnel to stand clear of transfer hose, then slowly open the main gas supply isolation fill valve (from source) to fill the trailer.

6.15.3 Post-Fill Shutdown

(a) Close the main gas supply isolation valve (from source) to begin shutdown and disconnect operations.

(b) Close the trailer manual fill valve.

(c) Purge and vent the transfer hose to atmospheric pressure as specified in the area of use.

(d) Disconnect the transfer hose restraining cable.

(e) Remove the transfer hose from the trailer and cap the hose and tailpiece ports.

NOTE: If a sample is required, follow the checksheet procedures as provided by the Chemical Analysis Branch. (Draw sample gas from the sample panel only.)

(f) Close all tube isolation valves (transfer is complete).

(g) Remove the ground and close the doors prior to moving the trailer.

(h) Remove barricades, warning signs, and wheel chocks.

6.15.4 Tube Trailer Withdrawal

(a) Ground the trailer at the connector located on the bumper.

(b) Secure the trailer doors.

(c) Chock/block trailer wheels. Also place at the front of the trailer a cone or sign indicating trailer is connected to the manifold.

(d) Put up the required barricades and signs.

(e) Open the gage isolation valve to ensure that the supply manifold has maintained pressure and is leak free.

(f) Connect an approved transfer hose to the trailer withdrawal tailpiece and receiving station.

(g) Secure the transfer hose restraining cables to the eyelets provided.

(h) Open all trailer tube isolation valves.

(i) Leak-check the trailer manifold piping.

(j) Open receiving station main isolation valve.

(k) Pressure purge the transfer hose assembly and maintain 40 to 100 psi in transfer lines.

(l) Leak-check transfer hose connections.

(m) Partially open trailer manual withdrawal valve.

(n) Withdraw personnel from area of transfer hoses.

(o) Open the trailer emergency shutoff valve from the remote location.

(p) Allow H_2 receiving station pressure to reach trailer pressure; then close the trailer emergency shutoff valve.

(q) Leak-check transfer hose connections.

(r) Fully open trailer manual withdrawal valve.

(s) Open the trailer emergency shutoff valve from the remote location to withdraw hydrogen for use.

6.15.5 Post-Withdrawal Shutdown

(a) From the remote location, close the emergency shutdown valve.

(b) Vent and purge the transfer hose to atmospheric pressure, as specified in the area of use.

(c) Close the manual withdrawal valve on the trailer.

(d) Close the receiving station main isolation valve to begin securing the system after use.

(e) Disconnect the transfer hose restraining cable.

(f) Remove the transfer hose from the trailer, and cap the hose and tailpiece ports.

(g) Close all tube isolation valves (the trailer is secure).

(h) Remove barricades, warning signs, and wheel chocks.

6.16 APPENDIX B—CLEANING HYDROGEN SERVICE SYSTEMS

6.16.1 Contamination Control

See Bankaitis and Schueller (1972) and NASA SP–5076.

Cleaning procedures shall be established and effective contamination controls developed to maintain the required cleanliness level for hydrogen systems.

Contamination of liquid hydrogen by solid air or oxygen-enriched air has resulted in serious explosions. Liquid hydrogen exposed to air can form slurries of solid oxygen and nitrogen that tend to be richer in oxygen than in air. These slurries can form explosive mixtures that can detonate with effects similar to those of TNT or other highly explosive materials.

Solid contaminants should be held to a minimum because they can contribute to the generation of static electricity in flowing systems. Explosions have occurred in filters contaminated with solid air; therefore, filter elements in liquid hydrogen servicing systems should be regenerated well before their capacity is reached. The warmup and purge of liquid hydrogen transfer systems usually regenerates the filters.

An effective control program must specify the degree of cleanliness, materials, and configuration required. Gross cleaning procedures (blast, mechanical, washing) should be followed by precision cleaning methods (vapor degreasing and ultrasonic). Suitable cleaning agents and methods for verifying surface cleanliness should be identified. Contaminants in liquid and gaseous hydrogen systems must be kept under control, and personnel must be trained to ensure control is maintained.

6.16.2 Cleanliness Requirements

All storage, transfer, and system components must be completely clean before being placed in service.

Liquid hydrogen systems must be free of any surface film, oxidant, grease, or oil. They also must be free of all matter (e.g., rust, dirt, mill scale, weld spatter, and weld flux) that could jam or clog valves and flow passages.

Valve stem seals and seats shall be carefully inspected and cleaned if necessary. The system must be dry and free of foreign material.

A system or dewar that has been out of service for a significant time should be inspected and cleaned as appropriate.

6.16.3 Recommended Procedure

A recommended cleaning procedure for a warm hydrogen system or component includes flushing to remove all loose particles (e.g., sand, grit, rust, and weld spatter). First, flush with 1,1,1-trichloroethane to degrease. Dry, and then flush with demineralized water.

For **liquid** hydrogen systems **only**, the system should be cold-shocked with liquid nitrogen to break off attached particles. The particles then can be flushed with liquid nitrogen into filters. The filters should be cleaned separately.

The system should be dried by evacuation. If the system cannot withstand a vacuum, it may be dried by flowing hot nitrogen gas through it. The nitrogen gas temperature should be well above the boiling temperature of water.

Systems should be dried by three cycles of evacuation and purging through a cold trap before filling with hydrogen gas. Usually three cycles will dry a system so that the cold trap shows no further collection.

All openings in cleaned systems should be closed in an airtight manner with metal covers and suitable gaskets. Good practice dictates similar treatment or the use of plastic containers for pipes and systems that are yet to receive a final cleaning.

6.16.4 Cleaning Filters

Frequency of cleaning depends on the amount of system use and impurities in the fluid. The operators must monitor increases in pressure drops, and clean the filters as needed.

Filters are cleaned by **disconnecting**, warming, draining, flushing (use 1,1,1-trichloroethane or ultrasonic cleaning), and then drying thoroughly. Filters must not be cleaned by back-flushing the system.

6.16.5 Periodic System Recheck

To ensure that the appropriate level of cleanliness is maintained, hydrogen systems should be periodically rechecked for contamination levels. Frequency of checking depends upon system use. The engineering organization responsible for a system should establish a cleanliness recheck schedule.

6.17 APPENDIX C—TECHNICAL CONTRIBUTORS AND REVIEWERS

6.17.1 Technical Contributing and Review Committee (Personnel with operational experience with hydrogen and oxygen)

Wayne Thomas	2820	Committee Chairman and editor; Rocket Engine and Test Facility engineering operations
Andrew Aron	7240	Hands-on and supervisory experience; propellant transfer and handling operations
Hank Bankaitis	0151	Aerospace Safety Research and Data Institute engineering experience; oxygen system cleaning
Bruce Block	2800	Safety Committee Chairman of area regularly using propellants
Russell Corso	4220	Launch vehicle and system engineering design
William Klein	2870	Engineering test operations at Plum Brook
John Kobak	8910	Rocket Engine and Test Facility engineering operations
John Kolacz	4130	Electrical system engineering design and standards
Edward Krawczonek	QSC	Hands-on and supervisory experience; Rocket Engine and Test Facility operations
David Kuivinen	7023	Chemical engineering; system cleaning procedures and standards
Scott Meyer	5350	Rocket Engine and Test Facility engineering operations
Scott Numbers	0152	Safety engineering standards and procedures for systems and materials
Larry Petraus	7290	Hands-on and supervisory experience; system cleaning and propellant transfer, handling, and test operations
Richard Sorge	2830	Propellant system and facility engineering operations

6.17.2 Other Reviewers

Additional major technical review of this chapter was provided by the following Lewis staff members:

Walter Bishop	2830	Philip Kramer	4330
Amy Bower	2870	Sheldon Meyer	4220
Dr. Robert Graham	Analex	Clayton Meyers	4220
Jerald Kennemuth	0120	Tim Schuler	Sverdrup

6.18 APPENDIX D—GLOSSARY FOR HYDROGEN AND OXYGEN CHAPTERS

Adiabatic compression. Compression of a gas in an adiabatic system. Since energy cannot be transferred to or from the surroundings in an adiabatic system, the compressional energy increases the energy (temperature) of the compressed gas.

Autogenous ignition. The phenomenon in which a mixture of gases or vapors ignites spontaneously with no external ignition source. It is frequently called "auto-ignition" or "spontaneous ignition."

Autoignition temperature. The lowest temperature at which a fuel in contact with air or an oxidizer will self-heat to ignition without an external ignition source. The autoignition temperature for a monopropellant is the temperature at which it will self-heat to ignition in the absence of an oxidizer.

Blast wave. A shock wave in air, caused by the detonation of explosive material.

Blast yield. Energy released in an explosion. The amount of energy is inferred from measurements of the characteristics of blast waves generated by the explosion.

Burn velocity. The propagation velocity of a flame through a flammable mixture. Burning velocities are absolute velocities measured relative to the velocity of the unburned gas; flame velocities are measured in laboratory coordinates and are not absolute.

Combustion wave. A zone of burning, propagating through a combustible medium, that is capable of initiating chemical reaction in the adjacent unburned combustible layers.

Critical diameter. The minimum diameter required for a tube to produce a stable spherical detonation into an unconfined environment. This term is sometimes used by other authors to describe the minimum tube diameter for propagation of a flame or of a detonation confined in the tube.

Deflagration. A rapid chemical reaction in which the output of heat is enough to enable the reaction to proceed and accelerate without input of heat from another source. Deflagration is a surface phenomenon in which the reaction products flow away from the unreacted material along the surface at subsonic velocity. The effect of a true deflagration under confinement is an explosion. Confinement of the reaction increases pressure, rate of reaction, and temperature and may cause transition into a detonation.

Detonation. A violent chemical reaction of a chemical compound or mechanical mixture in which heat and pressure are emitted. A detonation is a reaction which proceeds through the reacted material toward the unreacted material at supersonic velocity. As a result of the chemical reaction, extremely high pressure is exerted on the surrounding medium, forming a propagating shock wave that originally is of supersonic velocity.

Detonation cells. The cellular pattern left on a soot-coated plate by a detonation wave. The dimensions of a single cell (length and width) can be used to predict detonation limits and critical diameters.

Detonation limits. The maximum and minimum concentrations of vapor, mist, or dust in air or oxygen at which stable detonations occur. The limits are controlled by the size and geometry of the environment as well as the concentration of the fuel. "Detonation limit" is sometimes used as a synonym for "explosive limit."

Detonation wave. A shock wave that is sustained by the energy of a chemical reaction initiated by the temperature and pressure in the wave. Detonation waves propagate at supersonic velocities relative to the unreacted fluid.

Diffusion coefficient. The mass of material diffusing across a unit area in unit time at a unit concentration gradient.

Electrical arc/spark test. Method of determining the susceptibility of metals to ignition in oxygen by using an electrical arc or spark. Arc energy input and oxygen pressure are the major variables.

Explosion. The sudden production of a large quantity of gas or vapor, usually hot, from a smaller amount of a gas, vapor, liquid, or solid. An explosion may also be viewed as a rapid equilibration of a high-pressure gas with the environment; the equilibration must be so fast that the energy contained in the high pressure gas is dissipated as a shock wave. Depending on the rate of energy release, an explosion can be categorized as a deflagration, a detonation, or pressure rupture.

Explosive limits. The maximum and minimum concentrations of vapor, mist, or dust in air or oxygen at which explosions occur. The limits are controlled by the size and geometry of the environment as well as the concentration of the fuel. "Detonation limit" is sometimes used as a synonym for "explosive limit."

Explosive reaction. A chemical reaction wherein any chemical compound or mechanical mixture, when ignited, undergoes a very rapid combustion or decomposition, releasing large volumes of highly heated gases that exert pressure on the surrounding medium. Also, a mechanical reaction in which failure of the container causes the sudden release of pressure from within a pressure vessel.

Explosive yield. The amount of energy released in an explosion. Explosive yield is often expressed as a percent or fraction of the energy that would be released by the same mass of a standard highly explosive substance such as TNT.

Flammability limits. The maximum and minimum concentrations of a fuel (gas or vapor) in an oxidizer (gas or vapor) at which flame propagation can occur.

Free air or free gas (STP). Air or gas measured at a temperature of 60 °F (15.6 °C) and a pressure of 14.7 psia (101.4 kPa).

Hazardous (classified) location. A location where fire or explosion hazards may exist because of flammable gases or vapors, flammable liquids, combustible dust, or easily ignitible fibers or flyings.

Ignitable mixture. A mixture that can propagate a flame away from the source of ignition.

Ignition energy. The amount of energy needed to initiate flame propagation through a combustible mixture. The minimum ignition energy is the minimum energy required for the ignition of a particular flammable mixture at a specified temperature and pressure.

Ignition temperature. The temperature required to ignite a substance by using an ignition source such as a spark or flame.

Intrinsically safe system. A circuit in which any spark or thermal effect is incapable of causing ignition of a mixture of flammable or combustible material in air under prescribed test conditions and which may be used in hazardous NEC-classified locations.

Lower explosive limit (LEL). The minimum concentration of a combustible/ flammable gas or vapor in air (usually expressed in percent by volume at sea level) that will explode if an ignition source is present.

Lower flammable limit (LFL). The minimum concentration of a combustible/ flammable gas or vapor in air (usually expressed in percent by volume at sea level at temperatures up to 121 °C) that will ignite if an ignition source is present.

Shock wave. A surface or sheet of discontinuity set up in a supersonic field of flow, through which the fluid undergoes a finite decrease in velocity accompanied by a marked increase in pressure, density, temperature, and entropy, as occurs in a supersonic flow about a body.

Stoichiometric combustion. The burning of fuel and oxidizer in the exact proportions required for a complete reaction to give a set of products.

Unconfined vapor cloud explosion. Explosion that results from a quantity of fuel having been released to the atmosphere as a vapor or aerosol, mixed with air, and then ignited by some source.

Vapor explosion. A shock wave produced by the sudden vaporization of a superheated liquid coming into contact with a cold liquid.

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Chapter 7. PROCESS SYSTEMS SAFETY

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Chapter 7. PROCESS SYSTEMS SAFETY

7.1 SCOPE

This chapter presents general safe practices relating to all pressure vessels and pressurized systems. Specific safety considerations are included for pressure systems at the Lewis Center and Plum Brook Station. This chapter contains sections devoted to a particular commodity, such as cryogenics, pressurized gases, steam, cooling water, compressed air, and such. Each section addresses design considerations, testing, recertification requirements, and safety considerations.

7.2 RESPONSIBILITIES

The Lewis Recertification Program Manager is primarily responsible for ensuring that all pressure systems are safe to operate at the specified pressure and temperature. However, all personnel at the Lewis Center and Plum Brook who design, fabricate, construct, maintain, or operate pressure systems are responsible for understanding and conforming to the practices and provisions of this chapter.

7.3 PRESSURE VESSELS

7.3.1 Design Requirements for Pressure Vessels

Vessel design, fabrication, location, marking, and so on shall be in accordance with 29 CFR 1910 (OSHA regulations).

Stationary pressure vessels.—Stationary pressure vessels that (1) have a maximum allowable working pressure (MAWP) greater than 15 psig, with no limitation on size, or (2) have an inner diameter, width, height, or cross section diagonal exceeding 6 inches, or (3) are potentially lethal shall be designed in accordance with the rules of the "ASME Boiler and Pressure Vessel Code," Section VIII, Division I, "Pressure Vessels," or Division II, "Alternative Rules."

Portable or mobile vessels.—Portable or mobile vessels used to transport pressurized or hazardous commodities shall be designed, maintained, and operated in accordance with 49 CFR (DOT regulations). Vessels designed and fabricated according to these regulations should not be specified for permanent installation in pressurized systems.

Low-pressure tanks.—Stationary low-pressure tanks with MAWP between 0 and 15 psig that have a safety or environmental impact shall be designed in accordance with American Petroleum Institute (API) Standard 620, "Design and Construction of Large, Welded, Low-Pressure Storage Tanks"; API Standard 650, "Welded Steel Tanks for Oil Storage"; or an approved equivalent standard as determined by the Process System Safety Committee.

Flammable- and combustible-liquid storage tanks and vessels.—Flammable- and combustible-liquid storage tanks and pressure vessels shall be designed, fabricated, operated, and located in accordance with NFPA 30, "Flammable and Combustible Liquids Code."

Service life of pressure vessels.—Service life, determined by acceptable analysis or empirical data, shall be based on testing and analysis of fatigue, corrosion, creep, other failure mechanisms, or a combination of mechanisms. Lewis pressure vessels shall have a minimum design service life of 10 years.

Maintainability.—The designer shall provide for the following inspection and maintenance requirements:

(a) Access for inspection, and adequate work space and work clearance

(b) Interchangeability of like components, materials, and parts associated with the vessel

(c) Use of manufacturers' standard components and parts, and use of items within Lewis supply inventories wherever practicable

Relief protection.—All pressure vessels shall be provided with relief protection devices in accordance with the applicable division of Section VIII of the ASME Code.

(a) The relieving capacity of such devices shall be established in accordance with the applicable division of Section VIII of the ASME Code.

(b) Certification of flow capacity and marking of relief protection devices shall be in accordance with the applicable division of Section VIII of the ASME Code.

Corrosion allowance.—For all stationary vessels, corrosion allowance shall be evaluated in accordance with ASME Code, Section VIII, Divisions I and II.

Vessel attachments.—Design of and subsequent field alterations and changes to vessels shall minimize welding of attachments such as ladders, platforms, and pipe supports to the pressure boundary of the vessel.

7.3.2 Materials Requirements for Pressure Vessels

General requirements.—Materials used in the construction of pressure parts of pressure vessels shall conform to a specification in the "ASME Boiler and Pressure Vessel Code," Section II. Allowable stress values are given in Section VIII, Division I or II. Materials used for nonpressure parts, and attached to the vessel, shall conform to the requirements of Section VIII.

Tanks.—Materials for low-pressure tanks shall conform to American Society for Testing and Materials (ASTM) specifications.

Compatibility.—To prevent chemical reactions (including corrosion) between the contained commodity and contacted materials, all materials for use in pressure vessels shall be selected on the basis of proven compatibility. Guidance on material selection for compatibility may be found in MIL-HDBK-5, ASME Section II, and MSFC-HDBK-527. Manufacturers' data can also provide guidance on material selection. Note the following restrictions:

(a) When austenitic stainless steels are used, the welding process shall be qualified to ASTM-A262 or equivalent for the intended service, because these steels (300 series), when welded, are susceptible to intergranular corrosion due to carbide precipitation or sensitization. Guidance on corrosion protection may be found in the ASM "Metals Handbook," tenth edition.

(b) Copper or copper-bearing materials shall not be used in ammonia service.

(c) Aluminum storage vessels shall not be used in liquid oxygen service when pressure exceeds 250 psig.

7.3.3 Quality Assurance Requirements for Pressure Vessels

Manufacturer.—The pressure vessel manufacturer is required to maintain a quality control program in accordance with ASME Section VIII, Division I, Appendix 10, or Division II, Appendix 18. Documentation supplied by the manufacturer shall be adequate to verify design, material control, examinations and inspections, and welding. In particular, all welding personnel, procedures, and equipment shall be qualified in accordance with ASME Section IX.

Pressure testing.—Pressure vessels shall be pressure tested in accordance with the "Lewis Pressure Testing Handbook."

Stamping.—All newly fabricated vessels shall have a nameplate affixed, or be stamped, in accordance with the requirements in appropriate national consensus codes. All other vessels shall be identified as to maximum allowable working pressure (MAWP), test pressure, operating cycle, and temperature limits. In addition, the MAWP and system commodity shall be painted in a conspicuous location on each stationary pressure vessel.

Records.—A documentation file shall be provided for each vessel and tank. The documentation requirements are defined in the "Lewis Pressure Vessel/System Recertification Handbook."

Cleanliness.—Contamination control requirements shall be established commensurate with actual needs and the nature of the system and commodity. Cleanliness requirements for oxygen service are described in Chapter 5 of this Manual.

7.3.4 Recertification Requirements for Pressure Vessels

All pressure vessels shall be certified in accordance ASME Code requirements. All pressure vessels shall be included in a comprehensive recertification program, in accordance with the "Lewis Pressure Vessel/System Recertification Handbook."

Alterations or repairs to pressure vessels must be reviewed for compliance with applicable codes and standards and must be documented. Relief devices that protect pressure vessels from overpressure conditions are to be inspected at least every 2 years; they shall be removed, refurbished, and bench tested at 5-year intervals. A comprehensive nondestructive examination to recertify the vessel shall be performed at intervals not exceeding 20 years. (This recertification will help ensure continued safe operation of the vessel.)

7.4 PRESSURIZED SYSTEMS

7.4.1 General Requirements for Pressurized Systems

The design, material selection, fabrication, inspection, testing, and safeguarding of pressure systems can vary greatly in the effort to meet safety, functional, and cost objectives. This section sets forth minimum requirements for safe design of pressure systems.

7.4.2 Design Requirements for Pressurized Systems

Pressure systems and components shall be designed so that failure does not occur within expected design conditions. Piping systems shall be designed to meet or exceed one of the following, as applicable: American National Standard ANSI/ASME B31.1 "Power Piping" or B31.3 "Chemical Plant and Petroleum Refinery Piping." Particular system hazards and functional requirements warrant specific design, quality of material, inspections, and tests. Therefore, competent engineering judgment in the design of all pressure systems is required.

<u>System analysis requirements.</u>—Load, service life, and hazards must be considered when a system is being designed.

<u>Load</u>: All loads (direct and combined) on the system and its components shall be considered, including dynamic and static loads, thermally induced loads, external loads, and test loads. Codes establish specific load case combinations that must be compared with allowables. Minimum design shall be based on the worst case of expected load combinations. Loading frequency shall be used to evaluate safe life of the system on the basis of fatigue.

<u>Service life</u>: The service life shall be determined for system piping and components. Service life, determined by acceptable analysis or empirical data, shall be based on testing and analysis of fatigue, corrosion, creep, other failure mechanism, or a combination of mechanisms. Lewis systems shall have a minimum design service life of 10 years.

<u>Hazards</u>: In the selection of system configuration, materials, inspection, and test requirements, consideration should be given to potential system failures. Failure modes and effects analyses and other mitigation methods should be employed to ensure the general safety of personnel and the protection of equipment.

Maintainability.—Pressurized system design shall emphasize the need for access, inspection, service, replacement, repair, and refurbishment.

Mobile systems.—Mobile systems used to transport pressurized or hazardous commodities shall be designed, maintained, and operated in accordance with 49 CFR (DOT regulations).

Hazardous storage or waste systems.—Hazardous storage or waste systems shall be designed, operated, and maintained in accordance with 40 CFR, Parts 260 to 265, "Protection of Environment."

Flammable- and combustible-liquid storage systems.—Flammable- and combustible-liquid storage systems shall be designed, fabricated, located, and operated in accordance with NFPA 30, "Flammable and Combustible Liquids Code."

Relief protection.—All pressure systems shall be provided with relief protection devices in accordance with the applicable fabrication and design codes. In addition, the following must be observed:

(a) The relieving capacity of such devices shall be established in accordance with the applicable fabrication and design codes.

(b) Certification of flow capacity and marking of relief protection devices shall be in accordance with the applicable fabrication and design codes.

Corrosion allowance.—Corrosion allowance for all pressure systems shall be evaluated in accordance with the applicable design codes.

Supports and attachments.—Design of and subsequent field alterations or changes to pressure systems shall minimize welding of attachments such as ladders, platforms, and pipe supports to the pressure boundary of the system.

7.4.3 Materials Requirements for Pressurized Systems

General requirements.—Materials used in the construction of pressure system parts shall conform to one of the specifications listed in ANSI/ASME B31.1 or B31.3.

Compatibility.—All materials for use in pressurized systems shall be selected on the basis of proven compatibility. This will prevent chemical reaction between a reactive commodity and the contacted materials. Guidance on selecting materials for compatibility may be found in MIL–HDBK–5, AFML–TR–68–115, and MSFC–HDBK–527. When the system must accommodate corrosive conditions, the design must incorporate a corrosion allowance based on the design service life.

7.4.4 Fabrication, Installation, and Repair of Pressurized Systems

Fabrication, installation, and repair, including welding procedures and welder qualifications, shall be in accordance with ANSI/ASME B31.1 or B31.3, or the National Board inspection code, as applicable. Potential detrimental effects, such as intergranular corrosion, embrittlement, plastic deformation, and excessive deflection, shall be evaluated and avoided.

7.4.5 Quality Assurance Requirements for Pressurized Systems

Pressure testing.—Pressure testing shall be performed in accordance with the "Lewis Pressure Testing Handbook."

Relief protection.—All portions of the pressure system that can be overpressurized by single component failure or any combination of valve sequencing or other possible events shall be provided with relief protection devices in accordance with ANSI/ASME B31.3, Section 322.7.

7.4.6 Stamping (Labeling)

Pressure systems shall be marked and labeled in accordance with standard Federal and Lewis requirements.

7.4.7 Records

A documentation file shall be provided for each pressure system. The documentation requirements are defined in the "Lewis Pressure Vessel/System Recertification Handbook."

7.4.8 Cleanliness

Contamination control requirements shall be established commensurate with actual needs and the nature of the system and commodity. Cleanliness requirements for oxygen service are described in Chapter 5 of this Manual.

7.4.9 Recertification Requirement for Pressurized Systems

Prior to assembly, all new components in a pressurized system shall be certified in accordance with national consensus codes. All pressurized systems shall be included in a comprehensive recertification program. Alterations or repairs to pressure systems must be reviewed for compliance with applicable codes and standards and must be documented. Relief devices that protect systems from overpressure are to be inspected at least every 2 years; they shall be removed, refurbished, and bench tested at 5-year intervals. Other components shall be inspected regularly to detect any degradation. A comprehensive nondestructive examination to recertify the system must be performed at intervals not exceeding 20 years. This recertification will help ensure continued safe operation of the pressurized system.

7.5 CRYOGENIC SYSTEMS

7.5.1 Description

This section discusses stationary cryogenic systems. Mobile cryogenic systems are addressed in Section 7.8 (Mobile Equipment) of this chapter. The Compressed Gas Association (CGA) defines cryogenic fluids as those with a normal boiling point lower than −238 °F. At Lewis, cryogenic systems are used to store and distribute such cryogenic liquids as the following:

Fluid	Normal boiling point		
	°F	°R	K
Krypton	-244	216	120
Oxygen	-297	163	90.5
Argon	-303	157	87.2
Nitrogen	-320	140	77.8
Neon	-411	49	27.2
Hydrogen	-423	37	20.5
Helium	-452	8	4.4

A typical cryogenic system consists of a pressure vessel (called a "dewar"), pressure-relief devices, control valves, and distribution piping. The dewar is a double-walled pressure vessel with the system fluid contained in the inner vessel. The space between the vessels is filled with a powdered insulation (or is superinsulated) and is held at a vacuum with a vacuum pump, thereby providing an insulation barrier for the fluid in the dewar. A control system and heating coil allow the dewar to maintain an internal pressure. Cryogenic systems generally operate at pressures below 100 psig. Piping for cryogenic fluid distribution is either vacuum jacketed or heavily insulated.

7.5.2 Requirements for Cryogenic Vessels and Systems

In addition to conforming to the general requirements for pressure system safety, cryogenic vessels and systems must adhere to specific and unique requirements.

Cryogenic vessels.—Requirements for cryogenic vessels are as follows:

Design: Cryogenic vessels shall be designed in accordance with the ASME Code, Section VIII. When considering loadings, particular attention shall be given to the stresses from thermal contraction and expansion of the inner shell and support members. The outer shell of a multishell cryogenic vessel shall be designed for at least 15-psig external pressure.

Materials: Metals selected for use at cryogenic temperatures shall have no ductile-to-brittle transition. Many austenitic stainless steels (300 series), aluminum alloys, and nickel alloys exhibit this behavior. Guidance on material selection for compatibility with liquid oxygen, liquid hydrogen, and liquid fluorine may be found in AFSC DH-1-6.

Relief device: The inner vessel of a multishell cryogenic vessel shall have a relief device designed and maintained in accordance with Section VIII of the ASME Code. The outer vessel shall have relief protection to allow for a leak or failure of the inner shell.

Cryogenic systems requirements.—Requirements for cryogenic systems vary, depending on the cryogen.

Inert cryogens: Materials used in cryogenic service shall be of proven compatibility and of sufficient ductility at design temperature to preclude brittle failure. System configuration, line sizes, and insulation shall be designed to prevent excessive thermal stress, geysering, and water-hammer effects. Overpressurization protection must be provided in system sections that can be isolated. Components shall be rated and designed to operate at cryogenic temperature or installed at a sufficient standoff distance to operate at rated temperatures. Relief valves shall be mounted vertically and with sufficient standoff distance to prevent the valve from icing or failing to operate. Relief valves shall relieve into a vent system or into an area where no harm will come to personnel or equipment. Manual valves shall have extended stems, with the stems oriented vertically to prevent exposure of the valve packing material to cryogenic temperatures. Vacuum insulation spaces shall be provided with overpressurization protection in case of a leak in the pressure boundary of the inner transfer line.

Oxygen: Design and operation of systems for liquid oxygen storage shall conform to requirements contained in ANSI/NFPA 50, "Bulk Oxygen Systems at Consumer Sites." Oxygen pressure systems shall minimize potential ignition sources through design practice, material selection, and functional testing. In the design of systems and the selection of components and materials, consideration shall be given to ignition mechanisms such as high flow regions; pneumatic shock (adiabatic compression); actuation components that result in impact loading, galling, or mechanically induced ignition; cavity resonance that can lead to ignition of trapped containments in blind passages; flow induced vibration; and failure of electric sensors or heaters that can cause arcing, sparking, or overheating. Piping and components shall be free of hydrocarbons or any foreign matter. The reactivity of oxygen with various materials is known to increase greatly with increased pressure. More comprehensive information on oxygen service is described in Chapter 5 of this Manual.

Hydrogen: Design and operation of systems for liquid hydrogen storage shall conform to requirements contained in ANSI/NFPA 50B, "Liquefied Hydrogen Systems at Consumer Sites." Materials susceptible to hydrogen attack and hydrogen embrittlement shall not be used in hydrogen service. Materials that should be avoided include, but are not limited to, titanium, maraging steels, SA-517 or similar heat-treated steels, 400-series stainless steels, and MIL-S-16216 and precipitation-hardened stainless steels. More comprehensive information on hydrogen service is described in Chapter 6 of this Manual.

7.5.3 Testing and Recertification

To ensure the safety of personnel and equipment, testing and recertification of cryogenic systems are required.

Cold-shock testing.—New, altered, and repaired systems shall be cold-shock tested to verify the compatibility of material, equipment, and fasteners for cryogenic service. Prior to cold-shock testing, the vessel, components, and piping to be tested shall be inspected for proper assembly. Cold-shock testing shall be done in well ventilated areas, preferably out of doors, to prevent asphyxiation of personnel. Such tests shall be conducted in accordance with the "Lewis Pressure Testing Handbook."

Pressure testing.—Pressure testing of new, altered, and repaired systems shall be performed in accordance with the "Lewis Pressure Testing Handbook."

Recertification.—The Recertification Program calls for regular monitoring of all pressure components and piping of the cryogenic system. This monitoring helps ensure the integrity of the system. Users should verify current recertification status before placing a cryogenic system into service. All recertification activities shall be performed in accordance with the "Lewis Pressure Vessel/System Recertification Handbook."

7.5.4 Safety Considerations

Because of the nature of cryogenic systems, the following precautions should be taken:

(a) Avoid contact with fluid or equipment cooled to cryogenic temperatures, since cryogenic systems contain fluids that are extremely cold.

(b) The vapors of many cryogenic fluids are heavier than air; therefore avoid areas in unventilated spaces where low pockets of cryogenic vapor may accumulate.

(c) Provide proper ventilation for all portable dewar fill stations. Low-oxygen alarms should be used if proper ventilation cannot be provided.

(d) Vent relief devices to an area where no harm to personnel or equipment will result. Vent cans should be used wherever possible.

(e) Adhere to safety guidelines for personnel, given in Chapter 15 of this Manual.

7.6 STEAM SYSTEMS

7.6.1 Description

This section deals with the Basewide High Pressure Steam System, which supplies 100-psig (114.7 psia) saturated steam at 338 °F for distribution to 44 buildings in the original central laboratory area. The Steam Plant does not supply the South Rocket Test Facility Area, the West Area, or the Development Engineering and Annex Buildings. These areas have independent steam-generation capabilities. The Steam Plant houses five conventional industrial boilers with a combined maximum steam output of 200,000 pounds/hour. The boilers can be fired with either gas or number 2 fuel oil.

Five main steam headers exit the Steam Plant. Four of the headers are routed in basements and below-grade trenches. Most of the building shutoff valves are located in a pit beside the building. Other buildings have shutoff valves inside the building at each pressure-reducing station. Main header isolation valves are located in trenches throughout the system.

7.6.2 Requirements

Design.—Steam piping shall be designed in accordance with the ANSI/ASME Code B31.1, "Power Piping." Particularly, the design shall address thermal expansion and flexibility of components and supports. Cast-iron valves shall not be used in the steam system. For any alterations or repairs to the piping system, standard weldable fittings or sections of similar pipe should be used rather than patches. Welded repairs require, at a minimum, visual examination, magnetic particle testing, and a hydrostatic test after completion. Such testing shall apply to any welding done to a pressure-retaining part, including anchor supports welded to the main stream line.

Materials.—Metals selected must have allowable stress values as listed in Appendix A of the "Power Piping" Code and be in accordance with ASME SA, SB, or SFA specifications.

Relief device.—Pressure-reducing stations shall include a pressure-relief device on the low-pressure side that can relieve all the capacity of the high-pressure side in the event that the reducing valve fails to open. Safety valves shall conform to the requirements of ANSI/ASME B31.1.

7.6.3 Testing and Recertification

To ensure the safety of personnel and equipment, testing and recertification of the steam systems are required.

Pressure testing.—Pressure testing of the high-pressure steam system shall be performed in accordance with the "Lewis Pressure Testing Handbook."

Recertification.—The Recertification Program calls for regular monitoring of all pressure components and piping of the steam systems. This monitoring helps ensure the integrity of the system. All recertification activities shall be performed in accordance with the "Lewis Pressure Vessel/System Recertification Handbook."

7.6.4 Safety Considerations

Some safety considerations for steam systems are as follows:

(a) Because of the high temperatures associated with steam, care must be taken to avoid contact with steam, or pipes heated to steam temperatures.

(b) Relief devices shall vent to an area where no harm to personnel or equipment will result. Discharge piping shall be added to relief devices where needed.

7.7 HIGH-PRESSURE GAS SYSTEMS

7.7.1 Description

High-pressure gas systems at Lewis are used for the storage and distribution of various gases, including argon, oxygen, hydrogen, nitrogen, and helium. A typical high-pressure gas system consists of a storage vessel or bottle in which the compressed gas is stored, pressure-relief devices, control valves, pressure gages, and distribution piping. These systems are generally used for research tests, valve actuation, purging, and welding.

7.7.2 Design Requirements

Stationary compressed-gas vessels shall be designed in accordance with the "ASME Boiler and Pressure Vessel Code," Section VIII. Portable bottles ("K" bottles) are part of Section 7.8 of this chapter (Mobile Equipment) and shall meet the DOT requirements of 49 CFR 100 to 179. The associated piping for all high-pressure gas systems shall be designed in accordance with ANSI/ASME "Code for Pressure Piping," B31.

7.7.3 Testing and Recertification

To ensure the safety of personnel and equipment, testing and recertification of high-pressure gas systems are required.

Pressure testing.—Pressure testing of new, altered, and repaired systems shall be performed in accordance with the "Lewis Pressure Testing Handbook."

Recertification.—The Recertification Program calls for regular monitoring of all pressure components and piping of the high-pressure gas systems. This monitoring helps ensure the integrity of the system. Users should verify current recertification status before placing a high-pressure gas system into service. All recertification activities shall be performed in accordance with the "Lewis Pressure Vessel/System Recertification Handbook."

7.7.4 Safety Considerations

Because of the high pressures associated with these systems, there is a possibility of projectiles in the event of an explosion; therefore, vessels should be located in remote areas if possible. In addition, since many of the compressed gases are flammable, sparks or sources of concentrated heat must not be allowed to come in contact with the system; otherwise, the gas might ignite at a leak in the system, or it may burn internally.

7.8 MOBILE EQUIPMENT

7.8.1 Description

The mobile equipment at Lewis (compressed-gas cylinder trailers, dewars, liquid vaporizers, and tankers) is used for storing and distributing compressed gases and cryogenic liquids. Design, fabrication, operation, and testing of mobile equipment is governed by 49 CFR 100 to 179 (DOT regulations). All materials used for construction of mobile vessels must be suitable for use with the commodities to be transported and must comply with 49 CFR.

7.8.2 Definitions

Service pressure. The authorized pressure marked on the container (49 CFR). For example, for cylinder DOT 3AA2500, the service pressure is 2500 psig.

Cryogenic liquid. A refrigerated liquid having a boiling point lower than −130 °F at 1 atmosphere (49 CFR).

Compressed gas. Any contained mixture having a pressure greater than 40 psia at 70 °F or 104 psia at 103 °F, or any flammable liquid having a vapor pressure exceeding 40 psia at 100 °F (49 CFR).

7.8.3 General Requirements

Compressed-gas cylinders.—Requirements for compressed-gas cylinders are as follows:

(a) When compressed-gas containers are connected to manifolds, the manifold and its related equipment shall be of proper design for the product it is containing, considering the temperature, pressure, and flow. Manifolds shall be designed in accordance with ANSI/ASME B31.3, "Chemical Plant and Petroleum Refinery Piping."

(b) Each cylinder shall be fixed at the manifold end of the vehicle, with provisions for thermal expansion at the other end.

Compressed-gas cargo tanks.—The term "cargo tank" designates a compressed-gas container designed to be permanently attached to any motor vehicle or other highway vehicle. Such tanks must meet the following requirements:

(a) Each cargo tank, except tanks filled by weight, must be equipped with at least one liquid-level gauge as prescribed in 49 CFR. Additional gauges may be installed, but may not be used as primary controls for filling cargo tanks.

(b) Aluminum valves, piping, or fittings external to the jacket that retains lading may not be installed on cargo tanks used to transport oxygen or cryogenic liquid.

Cryogenic-liquid cylinders.—No cylinder shall be filled with a cryogenic liquid that is colder than the design service temperature of the container or that may combine chemically with any residue within the container to produce an unsafe condition. Cylinders containing cryogenic liquids must conform to the following requirements:

(a) A cylinder designed for transporting a cryogenic liquid shall be equipped with a pressure-control system that conforms to 49 CFR and that is designed and installed to prevent the cylinder from becoming liquid full.

(b) The jacket covering the insulation on a cylinder used to transport oxygen or any flammable cryogenic liquid must be made of steel.

(c) Aluminum valves or fittings with internal rubbing parts may not be installed on any cylinder used to contain liquid oxygen.

(d) Aluminum valves, piping, or fittings shall not be used on any cylinder used to transport flammable cryogenic liquids.

Cryogenic-liquid cargo tanks.—Cargo tanks shall not be loaded with a cryogenic liquid that is colder than the design service pressure of the packaging or that may combine chemically with any residue in the packaging to produce an unsafe condition. Cargo tanks used for cryogenic liquids must comply with the following requirements:

(a) The jacket covering the insulation on a cylinder used to transport oxygen or any flammable cryogenic liquid must be made of steel.

(b) Aluminum valves or fittings with internal rubbing parts may not be installed on any cargo tank used to transport cryogenic liquid oxygen unless the valve is anodized in accordance with ASTM B58–79.

(c) Aluminum valves, piping, or fittings external to the jacket that retains lading may not be installed on cargo tanks used to transport oxygen, cryogenic liquid, or flammable cryogenic liquid.

(d) A cargo tank used to transport cryogenic liquid oxygen must be provided with a manhole as prescribed in 49 CFR.

7.8.4 Testing and Recertification

To ensure the safety of personnel and equipment, testing and recertification of mobile equipment are required.

Pressure testing.—Pressure testing of new, altered, and repaired systems shall be performed in accordance with the "Lewis Pressure Testing Handbook."

Recertification.—The Recertification Program calls for regular monitoring of all pressure components and piping of the mobile equipment. This monitoring helps ensure the integrity of the system. Users should verify current recertification status before placing the mobile equipment into service. All recertification activities shall be performed in accordance with the "Lewis Pressure Vessel/System Recertification Handbook."

Cylinders.—Specific requirements apply to cylinder testing and recertification:

(a) All NASA owned, leased, or loaned Department of Transportation/Interstate Commerce Commission (DOT/ICC) specification cylinders shall be inspected, retested, and maintained on a regular 5-year schedule in accordance with 49 CFR.

(b) Cylinders due for periodic retest shall be tested and marked in conformance with the applicable requirements of 49 CFR.

(c) Compressed-gas cylinders manufactured in accordance with 49 CFR shall be accepted or rejected for continued service on the basis of the expansion data obtained from hydrostatic testing and visual inspection of each cylinder in accordance with the Compressed Gas Association (CGA) Pamphlet C-5 "Cylinder Service Life—Seamless, Steel, High-Pressure Cylinders."

(d) Regardless of the type of hydrostatic test method used, 49 CFR specifies that this periodic retest requires external and internal visual examination of the cylinder. It is recommended that these inspections be done prior to retest and that all rejected cylinders be condemned immediately.

(e) As specified in 49 CFR, the service life of a cylinder is terminated when a permanent expansion equaling 10 percent of the total expansion occurs during hydrostatic testing.

(f) Gases other than liquefied, dissolved, poisonous, or flammable gases may be compressed so that the cylinder is charged to a pressure 10 percent in excess of its marked service pressure, provided that the following conditions exist:

- The elastic expansion has been determined at the last test by water jacket method to be less than the prescribed elastic expansion rejection limit. The elastic expansion rejection limits for all 3A and 3AA specification cylinders are found in CGA Pamphlet C-5.

- The average wall stress and the maximum wall stress do not exceed the wall limitations of the material as prescribed by 49 CFR.

- The cylinders are equipped with frangible disk safety-relief devices (without fusible metal backing) that have a burst pressure not exceeding the minimum prescribed test pressure.

- An external and internal inspection at the time of retest showed that the cylinder is free of excessive corrosion, pitting, and dangerous defects.

- The cylinder is marked with a (+), indicating compliance with 49 CFR.

Cargo tanks.—Certain requirements apply to cargo tank testing and recertification:

(a) Each cargo tank shall be tested and inspected at least every 5 years in accordance with the specification of 49 CFR.

(b) Each tank must be subjected to a minimum internal pressure, as prescribed in 49 CFR, which can be hydrostatically or pneumatically generated.

(c) Each tank shall be inspected for corroded areas, dents, evidence of leaking under test pressure, or other conditions that might render a tank unsafe, and shall be rejected if any such unsafe condition exists.

(d) All piping, valves, and fittings on each tank shall be proved free from leaks at not less than the design pressure of the tank. In the event of replacement, all such piping, valves, and fittings shall be tested in accordance with 49 CFR.

7.8.5 Safety Considerations

The Facility Operations Division (FOD) is responsible for reviewing and maintaining technical surveillance, inventory, and inspection of the mobile equipment used at Lewis.

General safety.—In the interest of general safety, the following directives should be observed:

(a) **Since high-pressure air systems can be very dangerous when contaminated with oil, the distributor or user shall notify the owner about any condition that might permit a foreign substance to enter a container.**

(b) **Containers and their appurtenances shall be maintained only by the container owner or his authorized personnel.**

(c) **The prescribed markings or ownership markings shall be made in accordance with 49 CFR and shall not be removed or changed without owner authorization.**

(d) **The user shall not change, modify, tamper with, obstruct, or repair pressure-relief devices.**

(e) **Because cryogenic liquids and cold gases can cause frostbite injury on contact with the body, suitable precautions shall be taken to limit the possibility of injury when handling cryogenic liquids.**

(f) **Cryogenic liquid containers shall be stored and handled in well ventilated areas to prevent excessive concentration of the gas.**

Gas cylinder safety.—The following are gas cylinder safety directives:

(a) **All cylinders that are charged with a compressed gas and transported shall be equipped with one (or more) pressure-relief device(s) that has been selected and tested in accordance with CGA Pamphlet S-1.1.**

(b) **Each discharge for a safety-relief device on a cylinder containing a flammable compressed gas shall be arranged to discharge upward and unobstructed to the atmosphere.**

(c) **The interconnection of several containers by manifolding is subject to restrictions detailed in 49 CFR. Where manifolding is authorized, each container shall be equipped with isolation valves and safety-relief devices as required by 49 CFR.**

Gas cargo tank safety.—The following are gas cargo safety directives:

(a) **Each safety-relief device must have direct communication with the vapor space of the tank and be set at a maximum of 110 percent of the design pressure of the tank.**

(b) **No shutoff valve may be installed between the safety-relief device and the tank.**

Cryogenic-liquid cylinder safety.—**Each cylinder shall be provided with a safety-relief device and also shall be installed and maintained in accordance with 49 CFR. Each relief device must be installed so that the cooling effect of the contents during venting does not prevent effective operation of the device.**

Cryogenic-liquid cargo tank safety.—**Each cargo tank in oxygen and flammable cryogenic-liquid service must be protected by two independent pressure-relief device**

systems that are not connected in series. These devices must be selected in accordance with 49 CFR as follows:

(a) The primary system should consist of one or more pressure-relief valves.

(b) A secondary system should consist of one or more frangible disks or pressure-relief valves. For cargo tanks carrying carbon monoxide, the secondary system must be composed of pressure-relief valves only.

7.9 REFRIGERATION SYSTEMS

7.9.1 Description

This section deals with the Freon system being used at Lewis to refrigerate the Icing Research Tunnel. The type of Freon used in this system is also known as Refrigerant R–12, or dichlorodifluoromethane. It has a temperature of −22 °F at atmospheric pressure.

The Freon refrigeration system consists of a storage tank to contain the liquid when the system is not in use, pressure-relief devices, pumps or compressors to pressurize or move the liquid, control valves, and distribution piping. All components and piping are heavily insulated.

7.9.2 Design Requirements

The storage tank shall be designed in accordance with ASME Code, Section VIII. During the design, consideration shall be given to thermal contraction and expansion strain in the tank and supports. The piping shall be designed in accordance with ANSI/ASME B31.5, "Refrigeration Piping."

Metals selected for components shall remain ductile at liquid Freon temperatures. Alkali or alkaline-earth metals (aluminum, zinc, beryllium, etc.) are incompatible with Freon and must be avoided. Guidance on material selection for compatibility with liquid Freon may be found in ANSI/ASHRAE 15–89, "Safety Code for Mechanical Refrigeration."

7.9.3 Testing and Recertification

To ensure the safety of personnel and equipment, testing and recertification of the Freon system are required.

Pressure testing.—Pressure testing of the Freon refrigeration system shall be performed in accordance with the "Lewis Pressure Testing Handbook."

Recertification.—The Recertification Program calls for regular monitoring of all pressure components and piping of the Freon system. This monitoring helps ensure the integrity of the system. All recertification activities shall be performed in accordance with the "Lewis Pressure Vessel/System Recertification Handbook."

7.9.4 Safety Considerations

Leaks in a Freon system can be a source of illness or injury. If inhaled in large quantities, Freon vapor can cause heart irregularities and reduce the amount of oxygen that can be drawn into the lungs. Some safety considerations for working with refrigeration systems are as follows:

(a) Since Freon is heavier than air, it will sink; therefore, care should be taken to avoid low elevations in unventilated spaces where pockets of Freon might accumulate.

(b) Liquid Freon may cause frostbite, and it is a mild eye irritant, so avoid contact with skin and eyes.

(c) Refer to Loss Prevention Data Sheet 7-13, "Mechanical Refrigeration," published by Factory Mutual Systems, for refrigeration systems safeguards.

7.10 WIND TUNNELS

7.10.1 Description

Wind tunnels are structures that direct airflow over test objects, such as model aircraft, engines, wings, and rockets. Airflow can be produced by fans, compressors, or gas compressed into storage tanks. The air flows through the nozzle section, which increases the velocity to a desired speed. The test section contains the test object, which is connected to instrumentation that measures and records airflow, aerodynamic forces, and other parameters. A diffuser section reduces the air velocity before exhausting the air to the atmosphere or returning it to the fan or compressor. Depending on the tunnel, auxiliary systems such as refrigeration, high-pressure gas, compressed air, and others may be present.

Wind tunnels are usually designated by the size of the test section and the air velocity through the test section. There are six wind tunnels at Lewis, ranging from a 1- by 1-foot (1×1) test section to a 10- by 10-foot (10×10) test section. The 1×1 tunnel, which is in Building 37, uses the Combustion Air System as its source of air. It is a once-through tunnel that exhausts to the atmosphere.

The 8×6 supersonic tunnel and the 9×15 tunnel are located in two legs of the same tunnel loop. The 8×6 can be operated in aerodynamic mode, with air continuously circulating through the tunnel, or in propulsion mode, with airflow being exhausted to the atmosphere. The 9×15 operates only in aerodynamic mode, with air speeds of about 300 miles per hour. Large axial-flow compressors provide airflow for both tunnels; dryers, heaters, and coolers maintain the air at desired test conditions. Most of the exterior structure of this tunnel is constructed of reinforced concrete.

The 10- by 10-Foot Supersonic Wind Tunnel can also be operated in aerodynamic or propulsion mode. Mach numbers in the tunnel can be adjusted from 2.0 to 3.5. The exterior structure of this tunnel is mostly steel. Two sets of compressors provide airflow; dryers, heaters, and coolers allow adjustment to desired test conditions.

The Icing Research Tunnel is a World-War-II-vintage tunnel that is a National Historic Landmark. In 1987, much of the tunnel system was modernized. It has a 6- by 9-foot test section where speeds of up to 300 miles per hour are attainable. The tunnel operates with the refrigeration system and a set of spray nozzles to produce any desired icing conditions in the test section. A large wooden propeller provides airflow. The exterior structure of this tunnel is light-gage steel with an exterior blanket of insulation.

Plum Brook Station has a Hypersonic Tunnel Facility. This is a blowdown tunnel that uses a mixture of heated nitrogen and oxygen to simulate flow of air at desired Reynolds numbers. The tunnel exhausts directly to the atmosphere, aided by a steam jet ejector. Support systems for this tunnel are extensive and include high-pressure nitrogen, oxygen, and hydrogen systems and a large 125-psig steam system.

7.10.2 Design Requirements

Although there is no specific code for the design of wind tunnels, there are codes for the design of tunnel components:

(a) Pressurized tunnels and piping shall be designed in accordance with ASME Code, Section VIII and ANSI/ASME B31.1 or B31.3. Relief protection shall be provided in accordance with Section 7.4.2 of this chapter.

(b) Low-pressure tunnels shall be designed in accordance with standard structural engineering practices. Guidance on structural standards may be found in American Welding Society standard AWS D1.1–90.

(c) Thermal contraction and expansion effects shall be addressed during design of both high-pressure and low-pressure tunnels, because of the low temperatures obtained by high-velocity flow.

(d) Low-pressure tunnels shall be evaluated to determine conformance to national consensus standards such as AWS D1.1–90. As a minimum, the hoop stress associated with major structures shall be less than one-fourth of the minimum specified ultimate tensile strength of the material in the tunnel. If material properties are unknown, conservative assumptions or material samples may be used to establish tensile strength.

(e) Materials selected for the tunnel shall be appropriate for the conditions to which the tunnel is exposed, both internally, as a result of operating modes, and externally, as a result of the tunnel's location.

7.10.3 Testing and Recertification

To ensure the safety of personnel and equipment, testing and recertification of wind tunnels are required.

Modes of potential failure, including cyclic fatigue due to pressure, temperature, or vibration, as well as corrosion, erosion, or other inservice failure mechanisms, shall be identified and evaluated. The primary objective is to identify those areas that do not meet national consensus standards. Areas that are not in accordance with these standards can be addressed with respect to their impact on safety and reliability.

Pressure testing.—Pressure testing of wind tunnels shall be performed in accordance with the "Lewis Pressure Testing Handbook."

Recertification.—The Recertification Program calls for regular monitoring of all pressure components and piping of wind tunnels. This monitoring helps ensure the integrity of the system. All recertification activities shall be performed in accordance with the "Lewis Pressure Vessel/System Recertification Handbook."

7.10.4 Safety Considerations

Some important wind tunnel safety precautions are as follows:

(a) **The primary safety concern with regard to wind tunnels is the generation of missiles that can injure personnel and damage models or equipment. Therefore, all models and test instrumentation shall be secured before operation of the tunnel.**

(b) **Because of the high velocities and noise created by an operating wind tunnel, appropriate warning signs and indicators shall be installed around the tunnel.**

(c) **Blowdown or exhaust portions of tunnels shall discharge into an area where no hazard to personnel or equipment will result.**

(d) **Since some tunnels are remotely operated, evacuation signals and interlocks shall be used prior to operation, to ensure that all personnel are in safe areas.**

7.11 COMPRESSED-AIR SYSTEMS

7.11.1 Description

There are at least five different compressed-air systems at NASA Lewis: a 3000-psig air system for the 10- by 10-Foot Supersonic Wind Tunnel; 450- and 40-psig combustion air systems in the Engine Research Building (ERB); a 125-psig service air system, also in the ERB; and a 150-psig combustion air system in the Propulsion Systems Laboratory Building. The combustion air from compressors in Buildings 5 and 64 is supplied to 23 different buildings that are interconnected by a series of lines ranging from 10 through 54 inches in diameter.

There are 48 air-compressor/receiver tank units throughout Lewis. Thirty of these units are connected to the laboratory service air system. The remaining 18 are standalone units. The compressors range in size from 1/6 to 15 horsepower, and the pressure tanks range in capacity from 5 to 150 gallons.

7.11.2 Requirements for Piping

Design.—Compressed-air piping shall be designed in accordance with ANSI/ASME B31.1, "Power Piping." Particularly, the design shall address thermal expansion and flexibility of components and supports. Standard weldable fittings or sections of similar pipe should be used for any alterations or repairs to the piping system. Welded repairs require at least a visual examination, magnetic particle testing, and a hydrostatic test after completion. This shall apply to any welding done to a pressure-retaining part, including anchor supports welded to a compressed-air line.

Materials.—Metals shall be selected that have allowable stress values as listed in Appendix A of ANSI/ASME B31.1, "Power Piping" and that are in accordance with ASME SA, SB, or SFA specifications.

Safety device.—Pressure-reducing stations shall include safety or relief devices on the low-pressure side that can relieve all the capacity of the high-pressure side in the event that the reducing valve fails to open. Safety valves shall conform to the requirements of Section VIII of the "ASME Boiler and Pressure Vessel Code."

7.11.3 Requirements for Compressed-Air Vessels

Design.—Compressed-air vessels shall be designed in accordance with the ASME Code, Section VIII. Particularly, the design shall address thermal expansion between vessel, piping, and supports. Vessels should have manufacturer tags or clearly exposed markings to ensure that operating pressures and temperatures do not exceed the design range values.

Materials.—Metals shall conform to a specification in the "ASME Boiler and Pressure Vessel Code," Section II. Allowable stress values are given in Section VIII, Division I or II. Materials used for nonpressure parts, and parts attached to the vessel, shall conform to the requirements of Section VIII.

Safety device.—Safety devices shall conform to the requirements of Section VIII of the "ASME Boiler and Pressure Vessel Code." Discharge piping shall have a minimum number of elbows so as not to constrict discharge flow.

7.11.4 Testing and Recertification

To ensure the safety of personnel and equipment, testing and recertification of the compressed air systems are required.

Pressure testing.—Pressure testing of new, altered, and repaired systems shall be performed in accordance with the Lewis Recertification Program administered by FOD.

Recertification.—The Recertification Program calls for regular monitoring of all pressure components and piping of the compressed-air systems. This monitoring helps ensure the integrity of the system. Users should verify current recertification status before placing a compressed-air system into service. All recertification activities shall be performed in accordance with the "Lewis Pressure Vessel/System Recertification Handbook."

7.11.5 Safety Considerations

In the interest of safety, the following precautions should be taken:

(a) Vent relief devices to an area where the air will cause no harm to personnel or equipment. Add discharge piping to relief devices where needed.

(b) Do not mount the air compressor and drive on an air receiver tank because the vibrations may crack welds, thereby causing a tank explosion.

(c) Drain water from the tank frequently; this will prevent internal corrosion from thinning the tank shell.

7.12 ALTITUDE EXHAUST SYSTEM

7.12.1 Description

This section deals with large systems that operate at pressures below atmospheric. The Altitude Exhaust System at Lewis consists of large-diameter piping that enables altitude condition simulation in test cells and also serves as a means of exhausting engine combustion products. The system, which also contains spray coolers and fin-tube heat exchangers, is exhausted by blowers located in several buildings.

7.12.2 Design Requirements

Several aspects of the Altitude Exhaust System require special attention. The "ASME Boiler and Pressure Vessel Code" and "ASME/ANSI "Code for Pressure Piping" both require that vessels and components be designed for full internal vacuum or 15-psig external pressure. Since large-diameter piping is associated with the Altitude Exhaust System along with large coolers and heat exchangers, external reinforcing structures are often required. The internals of coolers and heat exchangers often have integral structural bracing to reinforce the walls of the vessel.

Because exhaust products are cooled with direct water spray, the interior of the Altitude Exhaust System is directly exposed to highly corrosive conditions. For this reason, generous corrosion allowances must be included in the design of vessels and components.

7.12.3 Testing and Recertification

To ensure the safety of personnel and equipment, testing and recertification of the Altitude Exhaust System are required.

Pressure testing.—Pressure testing of the Altitude Exhaust System shall be performed in accordance with the "Lewis Pressure Testing Handbook."

Recertification.—The Recertification Program calls for regular monitoring of all pressure components and piping of the Altitude Exhaust System. This monitoring helps ensure the integrity of the system. All recertification activities shall be performed in accordance with the "Lewis Pressure Vessel/System Recertification Handbook."

7.12.4 Safety Considerations

For safe operation of the Altitude Exhaust System, note the following:

(a) **The Altitude Exhaust System moves very large volumes of air; although the pressures are low, this amount of air moving through the system can cause damage if a failure occurs. The flat-sided exhaust coolers, because of their shape, are particularly vulnerable to weld failure from vibration and to internal corrosion. External reinforcement of vacuum vessels, piping, and components shall be inspected on a regular basis.**

(b) **Internal corrosion can be a significant problem in this system. Provisions shall be made for proper drainage and inspection of wall thickness of vessels, piping, and components.**

7.13 SPECIALTY SYSTEMS

7.13.1 Description

Systems included in this category are generally small package units used for such purposes as chemical injection or lubrication. Examples of specialty systems are boiler feedwater treating systems, cooling water treatment systems, and compressor lube and seal oil consoles. The fluids in these systems include biocides, strong acids and bases, and specialized oils, among others. System materials may include nonmetallic pressure-containing components.

7.13.2 Design Requirements

Specialty systems shall be designed in accordance with a national consensus code or shall be certified in accordance with Underwriter's Laboratories or other nationally recognized testing laboratories.

Special attention shall be paid to materials used in specialty systems, since the system fluid may have peculiar material requirements. The suppliers of the system hardware and the fluid should be consulted to ensure compatibility between the fluid and all pressure-containing, sealing, and nonmetallic components.

7.13.3 Testing and Recertification

To ensure the safety of personnel and equipment, testing and recertification of specialty systems are required.

Pressure testing.—Pressure testing of new, altered, and repaired systems shall be performed in accordance with the "Lewis Pressure Testing Handbook."

Recertification.—The Recertification Program calls for regular monitoring of all pressure components and piping of the specialty systems. This monitoring helps ensure the integrity of the system. Users should verify current recertification status before placing a specialty system into service. All recertification activities shall be performed in accordance with the "Lewis Pressure Vessel/System Recertification Handbook."

7.13.4 Safety Considerations

The following points must be considered for safe operation of specialty systems:

(a) **Unusual fluids may be contained in a specialty system. To alert personnel to potential hazards, all specialty systems shall be labeled in accordance with OSHA regulations 29 CFR 1910.**

(b) **Specialty systems may operate at high pressure or temperature.**

(c) **Since specialty systems are unique, the manufacturer or supplier shall provide detailed safety, maintenance, testing, and inspection information. This information shall be conveniently accessible to all personnel who may work with the system.**

7.14 HYDRAULIC SYSTEMS

7.14.1 Description

Hydraulic systems are used to move or control mechanical hardware. These systems are generally package systems with a hydraulic-fluid reservoir, filters, a pump, relief devices, switching valves, and a fluid system that usually has flexible hoses. Flexible hoses are required because of the motion caused by the hydraulic system. The pressures in a hydraulic system are very high, on the order of thousands of pounds per square inch. Large forces are produced by hydraulic actuators, and the systems are often remotely controlled.

7.14.2 Design Requirements

Pressure vessels in hydraulic systems shall meet the requirements of "ASME Boiler and Pressure Vessel Code," Section VIII, Division I or II. Piping systems shall meet the requirements of ANSI/ASME B31.3, "Chemical Plant and Petroleum Refinery Piping." Compliance with applicable standards of The Hydraulic Institute is also required.

7.14.3 Testing and Recertification

To ensure the safety of personnel and equipment, testing and recertification of hydraulic systems are required.

Pressure testing.—Pressure testing of new, altered, and repaired systems shall be performed in accordance with the "Lewis Pressure Testing Handbook."

Recertification.—The Recertification Program calls for regular monitoring of all pressure components and piping of the hydraulic system. This monitoring helps ensure the integrity of the system. Users should verify current recertification status before placing a hydraulic system into service. All recertification activities shall be performed in accordance with the "Lewis Pressure Vessel/System Recertification Handbook."

7.14.4 Safety Considerations

To safely operate hydraulic systems, note the following:

(a) **The actuating system shall be locked out and disabled before any work is performed on hydraulically actuated mechanisms.**

(b) **Large forces are produced by hydraulic systems; therefore, personnel shall remain a safe distance away from active hydraulic systems.**

(c) **Moving portions of hydraulic systems shall be replaced immediately if any wear or leakage is observed. These portions include hoses and cylinder seals.**

(d) **Many hydraulic fluids are flammable; they shall be handled in accordance with safe practices for flammable fluids.**

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Chapter 8. ELECTRICAL SYSTEMS SAFETY

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8.1 SCOPE

Electrical systems safety encompasses the responsibilities, regulations, and requirements that ensure a safe working environment for personnel engaged in electrical work at Lewis Research Center. This chapter sets forth minimum electrical safety guidelines and standards within the framework of Lewis safety policies and constraints. It is for professional designers and craftsman; it **is not** an instructional manual for untrained personnel. Nor is it a substitute for the detailed procedures judged necessary for the safe conduct of a specific task.

8.2 APPLICABILITY

The provisions of this chapter are applicable to all NASA employees and to all other agencies, organizations, and contractor personnel who design, construct, inspect, operate, maintain, or manage electrical systems within the confines of the Lewis Research Center at Cleveland and at the Plum Brook Station.

8.3 AUTHORITY

The authority for the electrical systems safety plan comes from the "NASA Basic Safety Manual," NHB 1700.1.

8.4 RESPONSIBILITIES

Specific responsibilities of individuals or organizations tasked with establishing safety requirements for electrical systems are as follows:

8.4.1 Area Safety Committees

The Area Safety Committees conduct third-party reviews of all proposed installations, modifications, and operations in their assigned areas, to ensure that all electrical systems meet minimum design, operational, and safety standards.

8.4.2 Electrical Applications Safety Committee

The Electrical Applications Safety Committee (EASC) reviews all major electrical power systems. This committee is primarily responsible for power distribution systems rated at 600 volts and higher. It also reviews novel electrical applications and advises Area and special Safety Committees concerning electrical systems safety.

The EASC issues operating Safety Permits for the Lewis Center and Plum Brook high-voltage substations and the associated power distribution systems and for the high-voltage variable frequency system in the Engine Research Building (Bldg. 5) complex. This Committee also reviews and permits any construction, maintenance, or repair that will modify a high-voltage one-line diagram or that will require a nonelectrical work crew to work in the vicinity of high-voltage lines or equipment, both inside and outside of substation areas, on the Lewis Center or Plum Brook premises.

8.4.3 Process Systems Safety Committee

The primary responsibility of the Process Systems Safety Committee is to ensure that the central process systems are designed and operated safely.

8.4.4 Line Management Personnel

It shall be the responsibility of line management personnel to ensure that the requirements of this chapter are adhered to in the design, construction, modification, operation, and maintenance of electrical systems.

8.5 CODES AND STANDARDS

The following codes and standards relate to the safe design, construction, operation, and maintenance of electrical power systems. These codes and standards establish **minimum** safety requirements. Electrical power systems at the Cleveland Center and Plum Brook Station shall meet or exceed the requirements of these documents.

8.5.1 "National Electric Code" (NFPA 70)

The "National Electric Code" (NEC) covers electrical conductors and equipment installed within or on public and private buildings and other premises. This document also covers electrical requirements for locations where there is a potential for fire and explosion due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings.

8.5.2 "National Electrical Safety Code" (ANSI C–2)

The NESC standard covers basic provisions for safeguarding persons from hazards arising from the installation, operation, or maintenance of (1) conductors and equipment in electric-supply stations, and (2) overhead and underground electric-supply and communication lines. It also includes work rules for the construction, maintenance, and operation of electric-supply and communication lines and equipment.

8.5.3 "Occupational Safety and Health Act"

The "Occupational Safety and Health Act" (Public Law 91–596) covers conditions, practices, or operations to ensure safe and healthful work places.

8.5.4 "NASA Basic Safety Manual" (NHB 1700.1)

This document contains policy and safety requirements which define the NASA Safety Program.

8.6 ELECTRICAL SHOCK

8.6.1 Hazards

Some persons who handle electrical equipment mistakenly believe that their tolerance to electric shock is related to their ability to withstand the pain of the shock. Actually, the lethal incidence is a function of the amount and duration of current passing through the chest. Furthermore, a possibly lethal current is only marginally higher than one ranked just painful and well within the range of industrial low-voltage power systems. Whereas asphyxiation is the physiological result of the first-zone of over-painful shock, ventricular fibrillation, or heart dysfunction, is the second-zone result. Not only is the latter nonselfcuring when the current stops, but also it is generally lethal within about 3 minutes.

Just as it is current, not voltage, that heats a wire, it is current that causes physiological damage. The effects of various 60-hertz currents on an average person are given in the following table:

Current	Physiological reaction
<1 mA	None
1 mA	Perception threshold
1-3 mA	Mild sensation
3-10 mA	Painful sensation
10 mA	Paralysis threshold of arms
30 mA	Respiratory paralysis
75 mA	Fibrillation threshold (0.5%)
250 mA	Fibrillation threshold (99.5%)
4 A	Heart paralysis threshold
>5 A	Tissue burning

As the magnitude of the current increases, statistically the current is more dangerous as a cause of burns than as a cause of heart failure. This is most likely due to the shorter exposure time. At very high voltages (above 2,300 volts), burns may not be severe since the victim initiates an arc that retracts (by reflex) his attempted grasp. In summary, humans are affected by the duration as well as the level of current. When contact is made in such a manner that the contacting part is retracted (e.g., a light finger touch during which the strong muscular contractions of the arm pull the fingers away), the shock is much less dangerous than one of the same current level incurred by "freezing" to the contact with a full hand grasp.

8.6.2 Resuscitation Training

Personnel who work with electrical equipment should be qualified in emergency first aid procedures and cardiopulmonary resuscitation.

8.7 GENERAL SAFETY CONSIDERATIONS

This section presents Lewis policies for work done on or near electrical power systems. Exceptions to these policies in the high-voltage electrical power system shall be approved by the High-Voltage Electric Power Systems Manager (7340). Exceptions to these policies in the low-voltage electric power system shall be approved by the Electrical/Mechanical Systems Manager (7320).

8.7.1 Configuration Control

Lewis has placed many electrical power systems, including their control and protective systems, under configuration control as established by the provisions of LMI 8820.1. Systems under configuration control are

(a) High-voltage electric power systems

(b) Low-voltage electric power systems

(c) Electrical power systems associated with major research facilities

Control of these systems is administered by various line organizations at Lewis. In some cases, the configuration of electrical systems serving major research facilities may be controlled by more than one line organization.

8.7.2 Electrical Isolation and Grounding

Lewis permits **switching** of energized electrical facilities by personnel certified to switch specific electrical systems. However, Lewis will **not** permit **work on** energized electrical systems.

To isolate electrical power apparatus, Lewis requires a minimum of one electrical open and the application of one visible safety ground.

Personnel safety grounds shall be applied in accordance with the "National Electrical Safety Code," ANSI C–2, Rule 444.

8.7.3 Switching Procedures

All scheduled electrical switching in the high-voltage electrical power systems and in all low-voltage unit substations located in buildings shall be done by using written electrical switching procedures. All switching procedures shall comply with the "National Electrical Safety Code," ANSI C–2, Rule 444. Each switchman shall be certified for the specific electrical power system, shall have a copy of the written switching procedure, and shall sign the written switching procedure, attesting to completion of each step of the procedure as it is completed.

8.7.4 Tagout Procedures

Tagout procedures shall be followed whenever work is being performed on a system or piece of equipment where operation of switches, valves, or similar devices could result in injury to personnel or damage to equipment. Tagout procedures are detailed in the Lewis Safety Manual, Chapter 9.

Electrical safety tags give visual notice of work being performed on or near electrical power apparatus. The safety and welfare of work crews depend on the diligent observance of these tags. **Intended or unintended violation of such warnings or unauthorized removal of these electrical safety tags shall be reason for disciplinary action.**

Whenever metal-enclosed electrical facilities (including high-voltage, metal-enclosed switchgears, unit substations, panelboards, and switchboards that normally isolate the public from electrically energized components) are opened, a safe-exclusion area shall be roped off, and a designated safety person shall be in attendance. No unauthorized personnel shall be permitted to enter the roped-off area without permission of the designated safety person. The designated safety person shall confirm that all personnel within the roped-off area are aware of exposed, electrically energized components. When the designated safety person leaves the area, either a new safety person shall be designated and in attendance or the opened facilities shall be closed and secured (i.e., locked if possible). **Failure to observe the requirements of this paragraph shall be reason for disciplinary action.**

8.7.5 Consider All Electrical Systems Hot

All electrical systems shall be considered energized until verified to be de-energized and grounded. Initial verification that the apparatus is de-energized shall be made with a tic tracer or noisy tester by using the hot-dead-hot technique. Subsequent verifications can be made by observing the open position of isolating breakers, switches, and links in sectionalizing boxes, or by intentionally disconnecting power apparatus or cables and installing one or more personal safety grounds.

8.7.6 Buddy System

The "buddy" system (a second person directly observing the operation) is to be used at Lewis. The provisions of this system shall be applicable to all aspects of electrical work, including field investigations supporting design activities, and all construction, operation, and maintenance activities. See Section 8.8.3 for special requirements for entering areas containing high-voltage equipment or circuits.

8.7.7 Work In Confined Space

Many electrical systems are contained within areas identified as confined spaces. Entry into confined spaces is governed by procedures detailed in the Lewis Safety Manual, Chapter 16.

8.7.8 Conduit Fish Wire

When fishing a tape or wire through a conduit or duct, personnel shall be stationed so as to prevent the free ends of the tape or wire from contacting energized equipment.

8.7.9 Validation of Operating Equipment

Operational electrical equipment shall be periodically validated to ensure that the dielectric strength has not fallen below safe levels. The responsible operations group shall maintain records specifying the method and frequency of the tests. After any repair that may have affected the equipment insulation and after periods of inactivity repair that may have affected the equipment insulation and after periods of inactivity exceeding those established by the Lewis Power System Manager, validation is mandatory prior to energizing the equipment. In general, power system equipment shall be tested for minimum values of 1 megohm or 1 megohm per 1000 volts of operating voltage, whichever is greater. A dc "megger" appropriate to the circuit voltage shall be used to obtain the readings. If lesser values are obtained, an appraisal by the responsible engineering group shall be made before energizing the equipment.

8.7.10 Color Coding of Indicating Lights

Color caps on indicating lights designating the condition or position of the contacts on circuit breakers or switches shall conform to the following:

(a) Contacts closed - red

(b) Contacts open - green

(c) Contacts automatically tripped open - amber (if furnished)

Color caps on indicating lights designating the position of a valve that allows or blocks flow shall conform to the following:

(a) Allows flow - green

(b) Blocks flow - red

These required designations may be waived by the Lewis Safety Assurance Office (SAO) if, on the basis of prior usage in a facility, the SAO deems it safer to use other designations. This special ruling shall require written notification and approval from the SAO.

8.7.11 Separately Derived Electric Power Systems

Separately derived electric power systems, such as those provided by engine-generator sets or battery-powered uninterruptible power supplies, present unusual safety considerations. Design, installation, operation, and maintenance of such systems shall conform to Articles 700, 701, and 702 of the "National Electric Code" (NFPA 70). Designs for such systems require the following approvals: for system voltages of 600 volts and greater and for 125-volt dc systems, the Lewis High-Voltage Power System Manager (organization code 7340) shall approve the design; for all other systems, the Electrical/Mechanical Systems Manager (organization code 7320) shall approve the design.

8.7.12 Battery Systems

Vented batteries and battery cells, regardless of electrode type, contain dangerous electrolytes that are subject to spillage. Overcharging or too rapid charging can cause boiling and spewing of electrolytes and production of explosive gases. The following precautions shall be observed in handling these devices:

(a) Face shields, rubber gloves, and protective rubber aprons shall be used whenever batteries or cells are being handled, filled, or charged.

(b) An eye wash station shall be located near each battery bank.

(c) Ample water shall be available to flood any electrolyte spill occurring in battery operations.

(d) Battery charging shall take place in well ventilated areas.

(e) No smoking, open flames, or sparking devices shall be permitted in a battery area.

(f) New battery installations shall be reviewed by the Lewis Safety Assurance Office to ensure adequate ventilation.

If the electrolyte should come into contact with skin or clothing, immediately treat it with water or a weak neutralizing solution. Electrolyte in the eyes, however, is a very dangerous situation; immediately flush the eyes with profuse amounts of water and **SEEK MEDICAL ATTENTION.**

8.7.13 Instrument Transformers

The following precautions must be observed in handling instrument transformers:

(a) Current transformer cases and secondaries shall be grounded. Where more than one set of current transformers are connected electrically, a ground point shall be selected that provides grounding for the network.

(b) Secondaries of current transformers shall never be opened while the primary circuit is energized.

(c) The case and one wire of the low voltage side of potential transformers shall always be grounded before energizing the transformer.

8.7.14 Valve Disconnect Switch

Any valve that exposes personnel to high pressures, large vacuum systems, or dangerous gases or fluids when equipment is energized shall have a disconnect switch at the piece of equipment. The disconnect switch shall open each ungrounded power lead and shall also open the power to the control circuit.

8.7.15 Eye Protection

Safety glasses, goggles, or face shields shall be worn when making electrical measurements on energized power circuits. Only devices designed for voltage testing and rated for the nominal voltage of the circuit under test shall be used to make voltage checks. Each test voltage indicator for distribution systems over 600 volts shall be verified before and after use by applying it to an energized circuit or by using an appropriate test unit.

8.7.16 Protective Suits

All personnel who energize or open electrical switchgear, panelboards, or switchboards shall wear protective safety suits made from Nomex or other suitable flash-proof material.

8.7.17 Ladders

Only fiberglass or wood ladders shall be used near electrical hazards. Metal ladders should be marked with signs or decals reading "CAUTION—DO NOT USE NEAR ELECTRICAL EQUIPMENT."

8.7.18 Hot Sticks

All hot sticks used at the Cleveland Center and Plum Brook Station shall be made of fiberglass. Field care, handling, and storage shall be per ANSI/IEEE Standard 516, Section 4.

8.8 SPECIAL HIGH-VOLTAGE SAFETY CONSIDERATIONS

8.8.1 Connections to High-Voltage Supply

All connections or modifications to high-voltage power systems require special considerations. At Lewis the high-voltage power distribution system is under configuration control, and LMI 8820.1 applies to all modifications and additions to the system. In addition, major facilities incorporating high-voltage systems and equipment are under configuration control of the responsible operating organizations. Each of these organizations has unique configuration control requirements covering changes to their controlled systems. At Plum Brook Station, configuration control is maintained by the Plum Brook Management Office. In general, prior to additions or modifications to such systems, formal engineering documentation, appropriate safety review, and final approval by the organization with configuration control responsibility are required.

8.8.2 High-Voltage Electric Power System Operating Instructions

The Lewis Power System Manager periodically issues numbered operating instructions applicable to high-voltage systems at Lewis. All personnel responsible for design, operation, maintenance, or repair of such systems shall become familiar with and follow these instructions.

8.8.3 Entry Into Substations

Entry into substations by other than the authorized maintenance personnel requires the designation of a safety person to monitor and control the activity (see Sec. 8.8.4). All entries to substations shall be coordinated through the Central Controls Operation Office power dispatcher. The designated safety person shall notify the power dispatcher upon entering and leaving the substation. Such notification shall include the purpose of the activity. **All unauthorized entries into substations, regardless of whether the substation is attended, unattended, locked, or unlocked, shall be reason for disciplinary action.**

8.8.4 Designated Safety Person

At Lewis the safety person who monitors and controls entry into substations, power manholes, cable tunnels or rooms, and transformer vaults is designated by the COTR for the high-voltage maintenance contractor. The safety person who monitors and controls entry into other controlled areas is designated by the TR for the contractor operating in that area. At Plum Brook, the safety person is designated by the Technical Services Group supervisor. The specific duties and requirements for the designated safety person in the high-voltage electric power systems are described in HVEPS–OI–012.

8.8.5 Switching

All electrical switching that requires clearance for work on electrical circuits is to be performed only by personnel who have been listed on an approved Qualified Operator's List (NASA Form C-580) as qualified switchmen for the specific equipment.

The following precautions must be observed:

(a) Disconnecting poles (hot sticks) and rubber gloves shall be used when operating high-voltage, hook-stick-operated disconnecting switches having open circuit voltages. The following table lists the minimum pole length for various voltages:

Voltage	Minimum length of disconnect pole, ft
750 to 7,500	4
7,501 to 50,000	8
50,001 to 73,000	12
73,001 to 138,000	16

(b) Rubber gloves with leather protectors shall be worn when operating any manually operated, mechanically connected, remotely controlled air break switch where the voltage exceeds 600 volts.

(c) No work shall be done on circuits or equipment disconnected from power sources by oil switches alone.

(d) A switchman operating any switch used for maintenance or for isolation of circuits above 600 volts shall be accompanied by a designated safety person who shall stand at a safe distance and be prepared to take any necessary steps in event of an emergency.

8.8.6 Work in Confined Spaces and Tunnels

Work in underground electrical tunnels, manholes or hand holes, and transformer vaults is subject to all requirements for work in confined space (Ch. 16). In addition, if high-voltage cables or equipment are contained within the space, a Safety Permit issued by the Electrical Applications Safety Committee is required. Specific requirements for entering these confined spaces are described in HVEPS–OI–004.

8.8.7 Cutting High-Voltage Cables

Cutting high-voltage cables when neither end of the cable is visible from the location of the cut presents unique safety considerations. At Lewis, the procedure to identify and cut high-voltage electric cables (rated 2,400 through 34,500 volts) is governed by HVEPS–OI–009.

8.8.8 Work On or Near High-Voltage Facilities

On high-voltage facilities.—Before work may be done on high-voltage power apparatus, two open breaks shall be provided in series on all electrical phases between the work site and each energy source, including backfeeds, and one open break shall be provided between the work site and potential transformers.

Visible protective safety grounds shall be provided either on both sides of the work site or at the work site.

When more than one work site exists on isolated high-voltage power apparatus, such as along an overhead 34.5-kilovolt distribution line, visible protective safety grounds shall be provided at both ends of the distribution line **and at each work site.**

Near high-voltage facilities.—When work is performed near high-voltage electrical power apparatus in air-insulated substations, nearby high-voltage power apparatus shall be isolated and grounded in accordance with Section 8.7.2.

When work is performed near high-voltage electrical cables and associated cable apparatus, cables and associated cable apparatus are not required to be de-energized. For such cases when cables or cable apparatus are requested to be de-energized, one electrical break is required. Utilization of protective safety grounds is optional.

Specific electrical isolation and grounding requirements for the high-voltage power systems are presented in HVEPS–OI–011, "Work On or Near High-Voltage Electrical Systems."

8.8.9 Lifting Equipment or Personnel Near Exposed Energized Electrical Parts

Distance.—Personnel working near and/or using hoisting, lifting, or other construction equipment near energized electrical lines or exposed terminals of electrical apparatus are subject to the minimum safe working distances established in HVEPS–OI–012. Construction equipment shall be separated far enough from high-voltage lines and apparatus so that a failure of a cable on cable-supported equipment would not result in the construction equipment approaching energized electrical facilities closer then the established minimum safe work distance.

Grounding.—All equipment shall be effectively grounded (to ensure proper fault protection) when being moved or operated in close proximity to energized lines or electrical apparatus. Consideration shall also be given to grounding the load, particularly if insulated lifting straps are in use. All such operations shall have a dedicated observer (without any other duties) to warn equipment operators of potentially hazardous situations and/or movements.

8.8.10 Fuses

Fuses on energized circuits above 34,500 volts shall not be removed. Procedures to be used when removing or replacing fuses on **unloaded energized circuits** shall conform to the following:

(a) On circuits rated 50 to 600 volts, insulating fuse tongs or extractors shall be used.

(b) On circuits rated 601 to 1,000 volts, lineman's type rubber gloves with leather protectors and either insulated fuse tongs or extractors shall be used.

(c) On circuits rated 1,001 to 34,500 volts, lineman's type rubber gloves with leather protectors, a protective Nomex suit, and insulated high-voltage sticks or tongs shall be used.

8.8.11 Rubber Insulating Gloves

Lineman's type rubber gloves shall be tested at least annually for the pertinent circuit voltage in accordance with ASTM D120-87, "Standard Specification for Rubber Insulating Gloves." In addition, a standard air test shall be made immediately before each use. Leather protectors shall always be worn over lineman's rubber gloves.

All certified switchmen shall have a personal pair of rubber insulating gloves, protective leather gloves, and a glove bag. In addition, two pairs of insulating gloves, protective leather gloves, and a glove bag shall be stored at each high-voltage substation and at each major research facility control room.

Personal gloves shall be constructed of three-ply insulating rubber sheet. The outer ply shall be constructed of stretched black rubber and the inner ply shall be constructed of a nonblack (preferably yellow) heavy rubber sheet. With this construction a minute puncture or slit of the outer stretched black rubber sheet would immediately pull apart, thereby revealing the inner rubber sheet. Whenever the inner rubber sheet is visible, the pair of gloves shall be discarded.

8.8.12 Hard Hats

All personnel entering high-voltage electrical substations, power manholes, electrical cable tunnels, electrical cable rooms, or transformer vaults shall wear a Class-2 hard hat conforming to 29 CFR 1910.135.

8.8.13 Safety Shoes

All personnel who regularly enter high-voltage electrical substations, power manholes, electrical cable tunnels, electrical cable rooms, or transformer vaults shall wear safety shoes meeting 29 CFR 1910.132.

8.8.14 High-Voltage Substation Contractor Work

For all work performed by contractors, **other than** that done by the high-voltage maintenance contractor within energized high-voltage substations or in the vicinity of energized exposed electrical lines or apparatus, the Government shall include the following safety requirements in the contract documents:

(a) Each contractor shall abide by all applicable OSHA, NEC, NESC, NASA, and Lewis safety rules and regulations.

(b) Each contractor must appoint an individual to be responsible for the electrical safety of each of the contractor work teams. Before starting the work, the contractor shall provide a document to the Government establishing that the appointed safety supervisor(s) is(are) qualified and knowledgeable in all required safety regulations. Safety persons shall ensure that each work area and a safe zone beyond the work area have been de-energized and made safe before permitting a team to work in the energized substation. Safety persons shall check to be sure that the desired circuits have been de-energized and properly grounded. Note: This requirement is not to be confused with the NASA designated safety person required by Section 8.8.3.

(c) Each contractor must install all barriers and rope guards deemed necessary to clearly define the work area and sufficient to protect the workers from inadvertently moving out of the safe work area. Work area separation from exposed energized lines and apparatus shall be as established in NHB 1700.1 Vol. I–B.

8.9 EQUIPMENT SAFETY TEST AND CHECKS

8.9.1 Tests to be Performed Prior to Initial Energization

Initial energization of all new electrical equipment shall be done only in the presence of the appropriate Government representative. Before the initial energization, the following tests must be done:

(a) All power feeder circuit breakers shall be checked for proper adjustments in accordance with the manufacturer's instructions. (Molded-case circuit breakers without solid state trip devices are excluded from this requirement.)

(b) All protective relays and other such devices shall be tested to be sure that they can operate in the range required. Where possible, tests shall include loading in at the current transformer secondaries to validate the circuitry as well as the device.

(c) All wiring shall be checked for conformity to the design and to functional requirements.

(d) All motors, cables, and switchgear shall be tested by the cognizant engineering group, in accordance with industry standards and manufacturer's recommendations, at voltage levels approved for the specific type of equipment. The following industry standards shall apply.

Equipment	Standard
Motors	ANSI/IEEE
Cables	
Paper insulated	AEIC
Rubber, ethylene propylene rubber, cross-linked polyethylene	ICEA
Switches	ANSI/IEEE

8.9.2 Protective System Checks

Protective relay settings shall be coordinated to provide selective tripping. The Power System Manager shall maintain a listing of the required settings and the frequency of periodic testing of all protective relays in use.

All protective relays on the Cleveland Center and Plum Brook power systems shall be checked and calibrated on a triannual basis. Every reasonable effort shall be made to perform an end-to-end test of the relay circuitry in the process of this check.

8.9.3 Circuit-Interrupting Devices

All circuit-interrupting devices shall be rated to interrupt the maximum short circuit of the power system at the point of application of the device.

Whenever a proposal is made to add circuit-interrupting devices to the system and whenever large loads are added or major system changes are made, the responsible engineering organization shall make system short-circuit studies to establish the circuit-interrupting duty requirements.

After any operation in which the circuit breaker opens under short circuit or fault conditions, circuit breakers shall be inspected and checked immediately to ensure suitability for reuse. When a trip occurs on breakers above 600 volts, the troubleshooting process shall verify the settings of all breakers between the fault and the breaker that tripped. (Molded-case circuit breakers without solid state trip devices are excluded from this requirement.)

To ensure satisfactory mechanical operation, all circuit breakers rated 34.5 kilovolts and above shall be operated at least once every 18 months, with the exception of those installed for 15 years or more, which shall be operated annually.

8.9.4 High-Voltage Insulation Testing

High-voltage test levels and procedures for all operating equipment shall be verified with the Electrical Power Systems Branch to ensure that the test voltage selected and/or procedure used is based on evaluations of the type and condition of insulation, age, damage, equipment history, and desired service, as recommended in ANSI/

IEEE 95, "Insulation Testing of Large AC Rotating Machinery with High Direct Voltage."

High-voltage dielectric testing shall be under the direction of a designated safety person. Testing shall be preceded by isolation, tagging, area securing, and grounding procedures as required. During testing, all safety precautions listed in ANSI/IEEE 95, Section 6, Paragraph 6.9 shall be followed.

8.10 EXPERIMENTAL EQUIPMENT

8.10.1 Safety Responsibility

Experimental electrical or electromechanical equipment that is under development, and therefore subject to frequent modifications, can present a particular hazard to personnel. The operating and emergency procedures and attendant hazards may change from day to day. The project manager is responsible for the safety of personnel and equipment associated with the development of experimental apparatus; however, a responsible member of the research team should be designated to establish correct working procedures, make a gross hazard analysis, and establish proper emergency procedures. Particular emphasis should be placed on de-energization of the equipment.

8.10.2 High-Voltage Capacitor Banks

Test personnel conducting experiments in which capacitor banks with voltages above 600 volts are employed shall have total knowledge of the experiment, the circuit, and the component layout; such personnel should also be fully trained in the operating and safety procedures to be used at that facility, including procedures to be used in the event of equipment failure. Some precautions and procedures are as follows:

(a) Each high-voltage test area shall be enclosed and protected by using gates and interlocks on the test controls. Since capacitors and related high-voltage component faults are a source of hazardous shrapnel, these components shall be isolated in a manner that precludes personnel injury or facility-related hazards such as fire.

(b) High-voltage warning signs shall be displayed in conspicuous locations. Flashing warning lights shall be used to indicate that tests are in progress.

(c) Shorting switches and grounding devices that normally discharge the capacitor bank shall be clearly visible to the test operator. These devices shall be fail-safe and shall function to a safe configuration with no electrical power.

(d) A voltmeter connected across the capacitor bank shall be clearly visible to the test operator at all times. A redundant voltmeter shall be installed at the capacitor bank.

(e) Prior to touching a high-voltage component within the test area, personnel shall determine, by using a grounding wand approved by the safety manager for the particular installation, that the capacitor bank is fully discharged to a building ground.

(f) Extreme caution shall be used on capacitor banks that are operated by dc voltages, since a dc capacitor bank will maintain a residual voltage for extended periods.

(g) Capacitors that are connected in series to form a bank shall be treated with great care, and each capacitor terminal in a series string shall be properly shorted to ground prior to making any changes to a test bank or circuit.

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Chapter 9. LOCKOUT/TAGOUT

Chapter 9. LOCKOUT/TAGOUT

9.1 SCOPE

This chapter sets forth the minimum standards required by the Occupational Safety and Health Administration (OSHA) as given in 29 CFR 1910.147, "Control of Hazardous Energy (Lockout/Tagout)." It applies to both Government and contractor personnel as a means of controlling exposures to potentially hazardous energy sources during work operations at the NASA Lewis Cleveland Center and Plum Brook Station. It imposes basic rules to be followed to ensure protection against harmful exposures, and it presents baseline implementation requirements from which detailed lockout/tagout procedures can be developed for individual systems and equipment items. Exceptions to these safety standards must be authorized by the cognizant Area Safety Committee and reviewed by the Safety Assurance Office (SAO).

These standards do not apply to operations known as "hot tapping." These shall be dealt with on an individual basis by the previously mentioned Committee and the SAO.

The procedures set forth in this chapter apply, during all work activities, to the control of potentially hazardous energy sources at any energy level capable of causing injury to personnel, damage to equipment, harm to the environment, and loss or compromise of test data. Energy sources and work activities include, but are not limited to, the following:

Energy sources	Work activities
Acoustical systems	Construction
Vacuum systems	Maintenance
Electrical systems	Installation
Pneumatic systems	Calibration
Hydraulic systems	Adjustment
Mechanical systems	Inspection
Compressed gas	Cleaning
Spring tension/compression	Repair
Suspended or moving loads	Close contact
Chemicals/fuels	
Cryogens	
Ionizing/non-ionizing radiation	
Optical systems (e.g., lasers)	
Thermal systems (i.e., heat/cold)	

9.2 DEFINITIONS

(a) Authorized employee. An employee responsible for placing his/her lock(s) and tag(s) on energy-isolating devices. (An employee shall meet the training requirements specified in Sec. 9.6 prior to being designated an authorized employee.)

(b) Area employee. An employee whose job requires him/her to operate or use a machine or equipment on which servicing or maintenance is being performed under lockout or tagout, or whose job requires him/her to work in an area in which such servicing or maintenance is being performed.

(c) Area Supervisor. An employee designated by the division chief to oversee worker safety in a given area, and who is responsible for implementing this lockout/tagout procedure. (An individual shall meet the training requirements specified in Sec. 9.6 prior to being designated an Area Supervisor.)

(d) Capable of being locked out. Equipped with an energy-isolating device that is designed with a hasp or other attachment or integral part to which, or through which, a lock can be affixed, or that has a locking mechanism built into it.

(e) Energized. Connected to an energy source or containing residual or stored energy.

(f) Energy isolating device. A mechanical device that physically prevents the transmission or release of potentially harmful energy, for example, a disconnect switch, a blind flange, or a physical block preventing motion of a mechanical device or valve. (Control components such as push buttons and operating levers that are used in normal operation to direct energy flow or release do not qualify as energy-isolating devices.)

(g) Energy source. A source of potentially harmful electrical, thermal, pneumatic, mechanical, hydraulic, chemical, or other energy (See Sec. 9.1.).

(h) General lockout/tagout. Method of securing energy-isolating device(s) to provide positive means of protection against potentially harmful energy release in instances requiring no more than three points of energy isolation.

(i) Group lockout/tagout. Method of securing energy-isolating device(s) to provide positive means of protection against potentially harmful energy release in instances when than three points of energy isolation are required or when multiple crafts or work crews may be exposed.

(j) Hot tap. A procedure used in repair, maintenance, and service activities in which a piece of equipment (pipeline, vessel, or tank) is welded on under pressure in order to install connections or appurtenances. It is commonly used to replace or add sections of pipeline without the interruption of service for air, gas, water, and steam distribution systems.

(k) Lockbox. Container for keys to departmental locks used for group lockout/tagout. Lockboxes must accommodate multiple hasps, and the organizational unit(s) having control over the lockboxes must place them at well-recognized, accessible locations.

(l) Lockout device. A device that utilizes a positive means (such as a keyed lock) to hold an energy-isolating device in the safe position, thereby preventing the energizing of a machine or equipment.

(m) Lockout. A procedure whereby one or more lockout device(s) is placed on an energy-isolating device(s) to ensure that neither the energy-isolating device nor the equipment being controlled can be operated until the lockout device is removed.

(n) Multiple lockout. A procedure used for lockout of more than one energy source.

(o) Multiple lockout device. A mechanical device, such as a hasp, enabling application of more than one lock to an energy-isolating device.

(p) Normal production operation. The utilization of a machine or equipment to perform its intended production function.

(q) Positive means of protection. Prevention of potentially harmful release of energy by a means that would require unusual and obvious measures to defeat.

(r) Servicing and/or maintenance. Workplace activities such as constructing, installing, setting up, adjusting, inspecting, modifying, and maintaining and/or servicing machines or equipment. These activities include any situation where the employee may be exposed to the unexpected energization or startup of equipment or release of hazardous energy.

(s) Setup. Any work performed to prepare a machine or equipment to perform its normal production operation.

(t) Tagout. Affixing a tag (NASA Form C-946, Rev. 6-87) on an energy-isolating device, in accordance with an established procedure (as described in Sec. 9.4), to indicate that the energy-isolating device and the equipment being controlled may not be operated until the tag is removed.

9.3 REQUIREMENTS AND RESPONSIBILITIES

These basic requirements underlie the formulation of the safety standards outlined in this chapter and guide their implementation:

(a) All lockout/tagout procedures must be developed and executed according to the standards of this chapter.

(b) If equipment is "capable of being locked out," potentially hazardous energy sources must be identified and (1) be kept, by positive means of protection, from accidentally releasing harmful energy, (2) be locked out, and (3) be tagged out during periods of activity/operation when exposures to those sources could cause harm.

(c) If equipment is not "capable of being locked out," alternative protective measures must be employed. These alternative measures must include tagout, and they must be directed by documented procedures, reviewed by the SAO, and approved by line management. The measures taken must provide a level of safety equivalent to that obtained by using a lockout procedure.

(d) Only authorized employees may lockout/tagout energy-isolating devices.

(e) Only authorized locks and tags (NASA Form C–946, Rev. 6–87) may be used (per 29 CFR 1910.147 (c)(5)).

(f) There may be no more than two keys for any lock: one to be held by the authorized employee, and one to be held under the control of the Area Supervisor and used for emergency removal only (see Sec. 9.4.4).

(g) Each authorized employee must affix his/her own lock/tag on the appropriate energy-isolating device or, in the case of group lockout, on the appropriate group lockbox.

(h) Locks/tags may be removed only by the authorized employee who installed the lock/tag. (Emergency exceptions to this rule are covered under Emergency Removal, Sec. 9.4.4.)

(i) No employee or work crew may work under the protection of a lock or locks belonging to another employee or work crew.

(j) Locks intended for use under the requirements of this chapter must not be used for any other purposes.

(k) "DANGER" tags shall be issued only by the organizational unit having jurisdiction over the equipment/system involved.

(l) A "DANGER" tag, NASA Form C–946 (Rev. 6–87), must be used in conjunction with each positive means of protection.

(m) "DANGER" tags must be complete and legible. Information entered on the tag must include the name of the organizational unit (and company, if placed by a contractor employee), the Area Supervisor, the authorized employee, the date of application, and any other useful information regarding the operation.

(n) Operating any device in violation of a lock or a "DANGER" tag is prohibited.

(o) All newly acquired equipment involving potentially hazardous energy sources must be outfitted to accommodate lockout devices per 29 CFR 1910.147 (c)(2)(iii).

(p) Upon replacement, major repair, renovation, or modification of existing equipment involving potentially hazardous energy sources, the equipment must be retrofitted to accommodate lockout devices per 29 CFR 1910.147 (c)(2)(iii).

(q) Supervisors of NASA and contractor personnel must ensure that employees under their supervision who are affected by or will use lockout/tagout procedures are trained to do so and are trained to recognize potentially hazardous energy sources, per Section 9.6.

(r) Violating any lockout/tagout rule or procedure may result in disciplinary action.

(s) Supervisors of NASA and contractor personnel must ensure that employees under their supervision comply with the requirements of this chapter and with the applicable lockout/tagout procedures.

9.4 SPECIFIC PROCEDURES

Procedures for lockout/tagout are divided into two categories, general and group. General procedures are typically used for work requiring few points of isolation and work done in-house. Group lockout/tagout procedures are typically required when there are multiple isolating devices, locks, tags, crafts, or outside crews or contractors involved in a work project. Tagout procedures, which are used with each energy-isolating device, are identical to lockout procedures except that a "DANGER" tag is placed on the energy-isolating device. Tagout procedures require additional measures to ensure that a level of protection equivalent to that of lockout is obtained (e.g., checklists or signoff sheets).

The lockout/tagout procedure is a logical sequence of events to provide maximum protection for personnel, equipment, the product, and the environment. This sequence must be followed during lockout/tagout procedures.

9.4.1 General Lockout/Tagout

Written procedures to control all potentially hazardous energy sources must be developed and documented by the Area Supervisor, approved by line management, and reviewed by the Safety Assurance Office before implementation. Such procedures must include

(a) A specific statement of the intended use of the procedure, including identification of the particular equipment or system to which it applies and the activity it is to cover

(b) Specific procedural steps and the assignment of responsibilities for each step. These steps are to include, but are not limited to,

- Notification of area employees, the supervisors and managers of the systems to be shut down, and others who may be affected by the shutdown

- Preparation for shutdown of equipment/system. Authorized employees must obtain and review documented lockout/tagout procedures and be aware of the type and magnitude of energy and the methods of control.

- Shutdown of equipment/system. Equipment/system must be de-energized or powered down by standard procedures.

- Isolation of equipment/system. All energy-isolating devices must be identified and operated to isolate the equipment/system from energy sources.

- Lockout/tagout of isolating devices. Authorized employees must place a lock or tag on each isolating device.

- Release or discharge of all potentially harmful stored energy. All residual stored energy must be released or discharged by accepted safe means.

- Verification of isolation. Assurance that the steps of isolation, lockout/tagout, release, or discharge have been carried out must be verified by physically attempting to operate the normal controls, thus ensuring that the equipment will not operate.

- Restoration of equipment or system to normal operation. Employees must ascertain that all materials and tools are removed from equipment. Locks and tags must be removed by the employee who applied them. The equipment or system must be returned to a normal operating state. Area employees, supervisors/managers, and others affected by the shutdown should be notified of lock or tag removal.

While following these procedures, conduct work safely and watch for unforeseen hazards. Be aware of changes of personnel, shifts, or crew (see Sec. 9.4.3).

If necessary, systems or equipment may be tested, calibrated, aligned, and so forth while energized; however, written procedures must be developed to govern such activities. Those procedures must include provisions for removing and replacing locks and tags, and they must be reviewed by the SAO and be approved by line management.

Approved procedures will be retained, but any subsequent revisions will have to be reviewed by the SAO and be approved by line management.

9.4.2 Group Lockout/Tagout

When group lockout procedures are used, they must afford a level of protection equivalent to that provided by general lockout procedures, and a master tag or checklist identifying points of isolation must be placed on or near the lockbox. Written procedures to control all potentially hazardous energy sources must be developed and documented by the Area Supervisor, approved by line management, and reviewed by the SAO before implementation. These procedures must include

(a) A specific statement of the intended use of the procedure, including identification of the particular equipment/system to which it applies and the activity it is to cover

(b) Specific procedural steps and assignment of responsibilities for each step. Procedural steps are to include, but are not limited to,

- Notification of area employees, the supervisors and managers of the equipment/systems to be shutdown, and others that may be affected by the shutdown. A lead supervisor or manager must be designated to oversee the lockout/tagout procedures if several crews, contractors, or departments are working on the same job.

- Preparation for shutdown of equipment/systems. Authorized employees must obtain and review documented lockout/tagout procedures and be aware of the type and magnitude of energy and the methods of control.

- Shutdown of equipment/systems. Equipment/systems must be de-energized or powered down by using standard procedures.

- Isolation of equipment/systems. All energy-isolating devices must be identified and operated to isolate equipment/systems from energy sources.

- Lockout/tagout of isolating devices by means of departmental or area locks/tags. Keys must be placed in the departmental or area lockbox. All authorized employees working on the project must sign off on the master checklist at the lockbox, thereby attesting that the locks/tags are appropriately placed. All authorized employees will place their locks on the hasp of the lockbox. The designated lead supervisor or manager will verify that these procedures have been followed.

- Release or discharge of all potentially harmful stored energy. All residual stored energy must be released/discharged from all equipment/systems by accepted safe means.

- Verification of isolation and checklist. Assurance that the steps of isolation, lockout/tagout, release/discharge have been carried out must be verified by physically trying to operate controls, thereby ensuring that the equipment will not operate.

- Restoration of equipment/systems to normal operation. All materials/tools must be removed from equipment/systems. Authorized employees must remove locks/tags and sign off on the master checklist. Equipment/systems must be returned to their normal operating states and area employees, supervisors/managers, and others affected by the shutdown should be notified of lock/tag removal.

While following these procedures, conduct work safely and watch for unforeseen hazards. Be aware of changes of personnel, shifts, or crews (see Sec. 9.4.3).

If necessary, systems or equipment may be tested, calibrated, aligned, and so forth, while energized; however, written procedures must be developed to govern such activities. Those procedures must include provisions for removing and replacing locks and tags, and they must be reviewed by the SAO and be approved by line management.

Approved procedures will be retained, but any subsequent revisions will have to be reviewed by the SAO and be approved by line management.

9.4.3 Shift Changes

If a task involves more than one shift, the Area Supervisor of the oncoming crew should be advised of any problems or safety concerns by the Area Supervisor of the offgoing crew. At a minimum, the briefing should include task description, a progress report, isolation actions taken, location of locks/tags, and any problems encountered.

The oncoming crew should use their own locks to replace the offgoing crew's locks. If tags are used, a checklist, as stated in Section 9.4, shall be used and reviewed by both the oncoming and the offgoing crews.

The crew that completes the task will be responsible for restoring power, testing equipment, and removing locks/tags. The Area Supervisor is ultimately responsible for the restoration of power, testing of equipment, and the removal of and accounting for locks/tags.

9.4.4 Emergency Lock Removal

When the authorized employee is unavailable to remove his or her lock/tag, that device may be removed by following these procedures:

(a) The Area Supervisor and the employee's supervisor are notified.

(b) The employee's supervisor notifies his/her manager.

(c) The employee's supervisor and the supervisor's manager verify that the employee is not available to remove his or her lock/tag (every possible effort to locate the employee shall be made prior to lock/tag removal).

(d) The employee's supervisor and the Area Supervisor shall remove the lock/tag.

(e) The employee's supervisor or manager contacts the employee's home to inform the employee about the lock/tag removal. If the employee cannot be contacted, then the employee's supervisor shall ensure that the employee is notified of the lock/tag removal before the employee resumes work at the facility.

(f) A report to the employee's line manager, documenting the action, shall then be filed by the employee's supervisor, with a copy to the SAO.

9.5 INSPECTIONS OR AUDITS

Inspections or audits of conformance to the standards of this chapter must be conducted at least annually by the Safety Assurance Office (SAO). The purposes of inspections/audits are to gauge the effectiveness of these standards and to guide their revision, thus ensuring their continued effectiveness. Results of inspections or audits are to be documented per OSHA 29 CFR 1910.147 (c)(6)(ii), submitted to the responsible organization, and kept on file in the SAO.

9.6 TRAINING

Training in the requirements of these safety standards must meet the requirements of 29 CFR 1910.147 (c)(7). Line management will provide such training to Area Supervisors/managers, authorized employees, area employees, and safety committee members.

The training must provide instruction in

(a) Recognization of potentially hazardous energy sources

(b) The purposes and functions of controlling potentially hazardous energy sources, as required by this chapter

(c) Regulations prohibiting any attempt to restart or re-energize machines or equipment that have been locked/tagged out

(d) Skills for applying energy-isolating devices, and procedures for lockout/tagout

(e) The limitations associated with tagout procedures per 29 CFR 1910.147 (c)(7)(ii)

Retraining/refresher training shall reaffirm employee proficiency and introduce new or revised control methods and procedures as necessary. Retraining will be required at least every 2 years and also when

(a) Changes in job assignment bring about changes in the types of potentially hazardous energy sources to which the employee might be exposed

(b) Changes in equipment or acquisition of new equipment bring about changes in the types of potentially hazardous energy sources to which the employee might be exposed

(c) Changes occur in energy control procedures

(d) Results of inspections/audits indicate training inadequacies

(e) These safety standards are revised in any substantive way

Results of training (i.e., attendees, topics covered, dates) are to be documented and submitted to the Technical and Administrative Training Branch.

9.7 APPENDIX—EXAMPLE OF LOCKOUT/TAGOUT PROCEDURE WHEN ELECTRICAL POWER OR CENTRAL AIR DISPATCHER IS INVOLVED

9.7.1 Electrical Systems Procedure With System Hazards

These steps and precautions are to be taken under the direction of the Electrical Power Dispatcher:

(a) Prior to starting work in an area, the authorized employee shall make a survey to locate and identify all energy-isolating devices to be certain which switch(es) or other energy-isolating devices apply to the equipment or process to be locked out and tagged.

NOTE: Other energy sources besides electrical (e.g., mechanical, pneumatic, etc.) also may be involved.

(b) The authorized employee shall know the type and magnitude of energy that the machine or equipment utilizes and shall understand the hazards thereof.

(c) Prior to locking out and tagging the equipment or process, the authorized employee shall notify all personnel who work with this equipment or process of the reasons for and the impending application of locks and tags.

(d) The authorized employee shall request approval from the Electrical Power Dispatcher to isolate, lockout, and tagout the proper system parts.

(e) After the Electrical Power Dispatcher has approved the authorized employee's request and has determined the extent of the isolation, the dispatcher shall instruct the authorized employee who will be performing the job to sequentially execute the following:

- Shut down the equipment
- Ensure that any stored energy (such as that in capacitors, etc.) is either dissipated or restrained by methods such as repositioning, blocking, and such
- Lock out and tag the energy-isolating devices

(f) The Electrical Power Dispatcher will install a "DANGER" tag for each switch or other device that must not be operated while the isolation is to continue. For each tag issued, the Electrical Power Dispatcher shall complete the Electrical Power Dispatch Tagout Record, NASA Form C–787.

(g) Under the direction of the Electrical Power Dispatcher, grounds shall be attached to locked out and tagged system parts as agreed upon by the authorized employee and the Electrical Power Dispatcher. The Electrical Power Dispatcher shall keep a record of any grounds that have been attached.

NOTE: Overhead line work shall not be performed after lockout and tagout until grounds have been placed on all three phases on both sides of the point of work.

(h) The authorized employee shall ensure that the isolation is accomplished by confirming that each isolating device is properly locked out and that tags are securely attached in a **conspicuous** location on each isolating device involved. The authorized employee shall not perform any work until isolation is complete, grounds are attached, and locks and tags are attached.

(i) After ensuring that no personnel are exposed, the authorized employee shall check that all energy sources have been disconnected, by operating the pushbutton or other normal operating controls to make certain that the equipment will not operate.

CAUTION: Return operating control(s) to "neutral" or "off" position after the test.

(j) If more than one group is engaged in work in an area at the same time, group lockout/tagout procedures shall be followed.

(k) **No attempt shall be made to operate any device that has been locked out and tagged.** No lock or tag may be removed until it has been released by the authorized employee at whose request it was issued, and then only after the Electrical Power Dispatcher has ordered the authorized employee to remove it.

(l) Should it become necessary to test the results of work done in a locked out and tagged area, then the locks, tags, and grounds may be temporarily removed at the request of the authorized employee after permission has been granted by the Electrical Power Dispatcher. After the test, the locks, tags, and grounds shall be replaced at the request of the authorized employee, providing the Electrical Power Dispatcher has given permission.

NOTE: All switching, placing, and removing of locks and tags shall be done by the authorized employees performing the work, under the direction of the Electrical Power Dispatcher.

(m) When the work in a locked out and tagged area has been completed, the authorized employee shall check the area around the equipment or process to ensure that all tools have been removed from the machine or equipment, all guards have been reinstalled, and all employees are in the clear. He/she must have absolute knowledge that everyone connected with the work on the system is accounted for before the locks and tags are removed.

(n) Prior to removing the locks and tags from the equipment or process, the authorized employee shall notify all personnel who work with this equipment or process of the impending removal of locks and tags.

(o) The authorized employee shall report to the Electrical Power Dispatcher that the work is finished and that the locks and tags may be removed.

(p) The Electrical Power Dispatcher shall instruct the authorized employee to remove the locks, tags, and grounds and to restore energy to the equipment or process.

9.7.2 Mechanical Systems Procedure With System Hazards

These steps and precautions are to be taken under the direction of the Central Air Dispatcher:

(a) Prior to starting work in an area, the authorized employee shall make a survey to locate and identify all energy-isolating devices to be certain which pipeline(s), compressor(s), valve(s), or other energy-isolating devices apply to the equipment or process to be locked out and tagged.

NOTE: Other energy sources besides mechanical (e.g., electrical, hydraulic, etc.) also may be involved.

(b) The authorized employee for the job shall know the type and magnitude of energy that the machine or equipment utilizes and shall understand the hazards thereof.

(c) Prior to locking out and tagging the equipment or process, the authorized employee shall notify all personnel who work with this equipment or process of the reasons for and the impending application of locks and tags.

(d) The authorized employee shall request approval from the Central Air Dispatcher to isolate, lockout, and tagout the proper system parts.

(e) Whenever electrical equipment is involved in a mechanical systems lockout and tagout procedure that is under the direction of the Central Air Dispatcher, the Central Air Dispatcher shall instruct the authorized employee to confer with the Electrical Power Dispatcher and arrange to have proper electrical equipment removed from service and locked out and tagged out in accordance with the Electrical Systems standards of these lockout and tagout standards. The Central Air Dispatcher also shall confer with the Electrical Power Dispatcher to be sure that proper electrical lockout and tagout has been made before permitting work to be started.

(f) After approving the authorized employee's request and determining the extent of the isolation, the Central Air Dispatcher shall instruct the qualified personnel who will be performing the job to sequentially execute the following:

- Shut down the equipment by operating valves and conducting other operations as required

- Ensure that any stored energy (such as that in springs, elevated machine members, rotating flywheels, etc.) is either dissipated or restrained by methods such as repositioning, blocking, bleeding down, and so on

- Lock out and tag the energy-isolating devices

(g) The Central Air Dispatcher shall forbid operation of the system and prevent such operation by initiating the tag function on the Central Control Building CRT status tabular display, which will indicate the locked out and tagged points on the appropriate operating schematic. The Central Air Dispatcher shall record these actions on the Central Air Dispatch Tagout Record, Electrical/Mechanical, NASA Form C-771.

(h) The authorized employee shall ensure that the isolation is accomplished by confirming that each isolating device is properly locked out and that locks and/or tags are securely attached in a **conspicuous** location on each isolating device involved. The authorized employee shall not permit any work to be done until isolation is complete and locks and tags are attached.

(i) After ensuring that no personnel are exposed, the authorized employee shall check that all energy sources have been disconnected, by operating the pushbutton or other normal operating controls to make certain that the equipment will not operate.

CAUTION: Return operating control(s) to "neutral" or "off" position after the test.

(j) If more than one group is engaged in work in an area at the same time, group lockout/tagout procedures shall be followed.

(k) **No attempt shall be made to operate or alter any system or equipment that has been locked out and tagged.** No lock or tag may be removed until it has been released by the authorized employee at whose request it was issued, or by his/her designated alternate, and then only after the Central Air Dispatcher has ordered the authorized employee to remove it.

(l) Should it become necessary to test the results of work done in a locked out and tagged area, then the locks, tags, and grounds may be temporarily removed at the request of the authorized employee after permission has been granted by the Central Air Dispatcher. After the test, locks and tags shall be replaced at the request of the authorized employee, providing the Central Air Dispatcher has given permission.

NOTE: All opening and closing of valves and other related operations, as well as placement and removal of locks and tags, shall be done by the authorized employee performing the work, under the direction of the Central Air Dispatcher. The Central Air Dispatcher shall record the actions on NASA Form C-771.

(m) When the work in a locked out and tagged area has been completed, the authorized employee shall check the area around the equipment or process to ensure that all tools have been removed from the machine or equipment, all guards have been reinstalled, and all employees are in the clear. He/she must have absolute knowledge that everyone connected with the work on the system is accounted for before the locks and tags are removed.

(n) Prior to removing the locks and tags from the equipment or process, the authorized employee shall notify all personnel who work with this equipment or process of the impending removal of locks and tags.

(o) The authorized employee shall report to the Central Air Dispatcher that the work is finished and that the locks and tags may be removed.

(p) The Central Air Dispatcher shall instruct the authorized employee to remove the locks and tags and restore energy to the equipment or process.

9.8 BIBLIOGRAPHY

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Chapter 10. IONIZING RADIATION

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Chapter 10. IONIZING RADIATION

10.1 SCOPE

This chapter describes the policies and responsibilities of the Lewis Radiation Protection Program and the general radiation protection procedures for the operation, handling, and use of radioactive materials and radiation-producing equipment. Specific details of radiation protection programs can be found in the Lewis "Radiation Protection Program Manual," the U.S. Nuclear Regulatory Commission Regulations, and recommendations of the National Council on Radiation Protection and Measurements.

10.2 APPLICABILITY

The provisions of this chapter are applicable to all the Cleveland and Plum Brook Station facilities of the Lewis Research Center except the Reactor Facility.

10.3 RESPONSIBILITIES

All personnel located at the Lewis Research Center who use radioactive materials or who operate radiation-producing equipment are responsible for understanding and conforming to the policies and procedures of this chapter.

Although the Executive Safety Board is responsible for the overall safety program and the Environmental Pollution Control Board for issues of environmental policy, including radiation protection, specific radiation safety responsibilities are assigned to the following organizations and individuals:

10.3.1 Radiation Safety Committee

The Radiation Safety Committee is responsible for reviewing and approving all radiation operations; it reports to the Center Director through the chairman of the Environmental Pollution Control Board. The Committee is approved by the U.S. Nuclear Regulatory Commission (NRC) as the controlling body for all Lewis' NRC-licensed activities except the Plum Brook Reactor and Mockup Reactor, which are the responsibility of the Plum Brook Reactor Facility Safety Committee.

10.3.2 Health Physics Office

The Health Physics Office of the Office of Environmental Programs is responsible for issuing health physics procedures; monitoring operations; educating personnel in radiation protection; advising operating groups regarding safe handling of radioactive materials and radiation-producing equipment; issuing radiation dosimetry equipment, including film badges, thermoluminescent dosimeters (TLD's), and pocket dosimeters, to personnel; issuing protective clothing and equipment, warning signs, and labels for radiation or radioactive materials; and ensuring that all operations meet the requirements of the NRC.

10.3.3 Radiation Safety Officer

The Radiation Safety Officer (RSO) is responsible for implementing the Lewis Radiation Protection Program and serves as the Chief of the Health Physics Office. The RSO is approved by the NRC and is responsible for monitoring and controlling the radiation protection aspects of operations at Lewis.

10.3.4 Area Safety Committees

Area Safety Committees are responsible for ensuring that all requests for radiation operations in their respective safety areas are reviewed by the Health Physics Office. The Area Safety Committees retain the authority to issue Safety Permits after the Health Physics Office approves the request.

10.3.5 Supervisors and Authorized Users

Supervisors and authorized users of radioactive materials or radiation-producing equipment are responsible for maintaining their radiation operations in accordance with the requirements of this chapter and the Lewis Radiation Protection Program. If an operation is suspected of being deficient or hazardous, the supervisor shall stop the operation and notify Health Physics personnel.

10.3.6 Office of Environmental Programs

The Office of Environmental Programs is responsible for managing, directing, and implementing the environmental programs of Lewis and has functional management of the Lewis Radiation Protection Program.

10.4 DEFINITIONS

(a) Ionizing radiation. Any or all of the following: alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, protons, and other atomic particles. Ionizing radiation does not include sound waves, microwaves, radio waves, or visible, infrared, or ultraviolet light.

(b) Radioactive material. Any material that emits radiation, whether or not it is subject to licensing control. Such material may be radioactive inherently or radioactive as a result of activation or contamination, either fixed or loose.

(c) Special nuclear material (SNM). Plutonium, uranium-233, uranium enriched with the isotope 233 or the isotope 235, or any other material that the NRC determines to be special nuclear material, or any material artificially enriched by any of the foregoing. SNM does not include source material.

(d) Source material. Uranium or thorium or any combination thereof in any physical or chemical form, or ores that contain 0.05 wt % or more of uranium or thorium or any combination thereof. Source material does not include SNM.

(e) Byproduct material. Any radioactive material (except SNM) yielded in, or made radioactive by exposure to the radiation incident to, the process of producing or utilizing SNM.

(f) Rem. A measure of the dose of any ionizing radiation experienced by body tissue, determined by its estimated biological effect.

(g) Rad (radiation absorbed dose). A measure of absorbed energy per unit mass.

(h) Roentgen. A unit of exposure to ionizing radiation; the amount of gamma rays or x-rays required to produce ions carrying one electrostatic unit of charge in 1 cubic centimeter of dry air under standard conditions.

(i) Radiation area. Any area, accessible to personnel, in which radiation exists at such levels that a major portion of the body could receive in any 1 hour a dose in excess of 5 millirem, or in 5 consecutive workdays a dose in excess of 100 millirem.

(j) High-radiation area. Any area, accessible to personnel, in which radiation exists at such levels that a major portion of the body could receive in any 1 hour a dose in excess of 100 millirem.

(k) Very high radiation area. Any area, accessible to individuals, in which radiation levels are high enough for an individual to absorb a dose in excess of 500 rad in 1 hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

(l) Restricted area. Any area to which access is controlled to protect individuals from exposure to radiation and radioactive materials. An area that is normally unrestricted may be temporarily restricted upon approval by the Health Physics Office.

(m) Authorized user, or user. An individual approved by the Radiation Safety Committee to use and/or supervise the use of radioactive materials or radiation-producing equipment.

(n) Contamination (radioactive). The deposition or presence of radioactive material in any place where its presence is considered to be detrimental to persons, equipment, or operations, that is, the presence of unwanted radioactive material.

(o) Personnel-monitoring equipment. All devices designed to be worn or carried by an individual to measure the radiation exposure of the individual (e.g., film badges, pocket dosimeters, thermoluminescent dosimeters, etc.).

10.5 RADIATION SAFETY COMMITTEE

The Radiation Safety Committee (RSC) is established pursuant to Title 10 of the Code of Federal Regulations, Part 33 (10 CFR 33). The primary purpose of this Committee is to maintain radiation safety standards within Lewis Research Center at Cleveland and Plum Brook in conformance with 10 CFR, Parts 19, 20, and 33. In addition, the Committee functions as a review body for all radiation safety concerns at Lewis. Authority to fulfill this responsibility and to perform the functions of this Committee is granted by the Center Director. The Committee reports to the Director through the chairman of the Environmental Pollution Control Board. Specific Committee functions are described in Section III of the "Radiation Protection Program Manual."

10.6 RADIATION SAFETY OFFICER (RSO)

The RSO is appointed by the Center Director to implement the Radiation Protection Program at Lewis. The specific responsibilities of the RSO are described in Section IV of the "Radiation Protection Program Manual."

10.7 RADIATION PROTECTION PROCEDURES

10.7.1 Authorization of Users

Only those persons who have been authorized by the Radiation Safety Committee or its designee shall work with radioactive materials or radiation-producing equipment. Specific authorization procedures are described in Section V.A. of the "Radiation Protection Program Manual."

10.7.2 Protective Apparel and Equipment

The individual user and the user's supervisor must ensure that the user wears appropriate protective clothing whenever contamination of personnel or personal clothing is possible. Specific details regarding protective clothing are described in Section V.B. of the "Radiation Protection Program Manual."

10.7.3 Contamination Control

Each individual working with radioactive materials must maintain contamination levels as low as reasonably achievable and must ensure that contamination is not carried beyond restricted areas. The Lewis "Radiation Protection Program Manual" details specific procedures regarding personnel contamination and area contamination, and specifies maximum permissible contamination levels for the following: skin surfaces and personal clothing; laundered protective clothing; unrestricted areas; and restricted areas. Specific procedures and standards are described in Section V.C. of the "Radiation Protection Program Manual."

10.7.4 Emergency Procedures

The authorized user or any person who observes any incident where personnel may be overexposed to radiation due to a spill or loss of control of radioactive material shall report the incident to the RSO of the Health Physics Office. Fires or injuries to personnel in areas where radioactive materials are used shall be reported by dialing 911. Specific reporting requirements are described in Section V.D. of the "Radiation Protection Program Manual."

10.7.5 Restricted Area Controls

Restricted radiation, high-radiation, and very-high-radiation areas, as designated by the RSO, shall be marked clearly with signs, and where personnel-monitoring equipment is required, the marking shall include a statement to this effect. Standard signs, prescribed in 10 CFR Part 20, bearing the radiation "CAUTION" symbol shall be available from the RSO. Specific controls are described in Section V.E. of the "Radiation Protection Program Manual."

10.7.6 Control of Radioactive Material and Radiation-Producing Equipment

Procurement and receipt.—Purchase requests for radioactive material or radiation-producing equipment shall be approved by the RSO or designee. Upon receipt, packages containing radioactive material must be surveyed promptly for contamination and radiation levels. Specific procedures are described in Section V.F. of the "Radiation Protection Program Manual."

Utilization and storage.—All storage and use areas for radioactive material shall be approved by the RSO. Each room or area in which radioactive material is used or stored shall be properly posted, and each container of radioactive material shall be properly labeled. Specific procedures are described in Section V.F. of the "Radiation Protection Program Manual."

Handling sources with high radiation levels.—Some radionuclides, because of a combination of activity and particle or photon energy, present a significant hazard to personnel in the immediate vicinity of an unshielded source. The sources of concern are those that produce radiation levels from which a major portion of the body could receive a dose in excess of 100 millirem in any 1 hour. Specific procedures must be followed in order to keep personnel exposures as low as reasonably achievable. These procedures are described in Section V.F.3. of the "Radiation Protection Program Manual."

Transfers.—Internal transfers of licensed material shall be properly documented, the material properly identified, and radiation levels properly controlled. Offsite transfers shall receive the same considerations. In addition, the RSO or designee shall approve and maintain a record of all radioactive material shipments and shall certify that materials are properly classified, described, packaged, marked, and labeled in accordance with applicable regulations (both NRC and DOT). Specific procedures are described in Section V.F.4. of the "Radiation Protection Program Manual."

Radioactive waste disposal.—Radioactive wastes shall be disposed of by transfer to a licensed radioactive waste disposal contractor, with limited exceptions. Requests for disposal shall be made to the RSO. The disposal of radioactive wastes shall be coordinated by Health Physics Office personnel.

Liquid waste must be disposed of in accordance with the provisions of 10 CFR 20. Such disposal must be approved by the RSO.

Release of radioactive gases or particulate radioactive material into the air must be done in accordance with the provisions of 10 CFR 20. Specific waste disposal procedures are described in Section V.F.5 of the "Radiation Protection Program Manual."

10.7.7 Personnel-Monitoring Equipment and Bioassay

Personnel-monitoring equipment is issued to all personnel who work in radiation areas. In addition, bioassays are performed for appropriate personnel designated by the RSO. Monitoring results shall be available to the user and the Radiation Safety Committee. Specific monitoring procedures are described in Section V.G. of the "Radiation Protection Program Manual."

10.7.8 Maximum Permissible Dose

No individual shall knowingly expose him/herself or cause others to be exposed to levels of radiation greater than those delineated by the Radiation Protection Program, except in cases of extreme emergency. The lowest practical daily exposure should be striven for in every operation. The maximum permissible occupational exposures are described in Section V.H. of the "Radiation Protection Program Manual."

10.7.9 Exposure of Minors

Occupational dose limits for individuals under 18 years of age are limited to 10 percent of the permissible occupational limits and to 10 percent of the limits for airborne radioactive material.

10.7.10 Exposure of Pregnant Women

Dose limits for pregnant women are limited to 500 millirem for the term of the pregnancy.

10.8 RADIOGRAPHIC WORK PERFORMED ONSITE BY OFFSITE CONTRACTORS

Lewis is responsible for controlling the radiation exposure of all persons onsite, whether from activities by Lewis personnel or by other personnel. When work such as industrial radiography is to be performed onsite, the RSO or the Health Physics Office should be notified as soon as possible.

10.9 USE OF X-RAY DIFFRACTION EQUIPMENT

10.9.1 Policy

It is the policy of Lewis to control the use of x-ray diffraction equipment in such a manner as to avoid unnecessary exposure, minimize necessary exposure, and ensure that no individual radiation exposure exceeds the recommended limits. This should be accomplished with minimal restrictions on operations.

10.9.2 Limitations

Limitations apply primarily to x-ray diffraction equipment. However, any electronic tube operating at potentials above 5,000 volts may produce nonuseful x-rays. Examples are cathode ray tubes, electron microscopes, and particle accelerators. Radiation protection requirements for these sources are established by the Health Physics Office; questions and problems related to such devices should be referred to the RSO.

10.9.3 Equipment Operation

The Lewis Radiation Protection Program describes specific responsibilities for supervisors and users of x-ray diffraction equipment. Radiation safety training for operators must be provided, and the equipment itself must be approved. Detailed procedures are described in Part B, Section 7 of the "Radiation Protection Program Manual."

10.9.4 Biological Effects of Overexposure

X-ray diffraction equipment generates extremely high-intensity ionizing radiation that can cause severe and permanent injury if not controlled. Radiation levels as high as 400,000 roentgens/minute at the tube port are possible at 50 kilovolts and 20 milliamps; the dose rate from a diffracted beam may be as high as 80 roentgens/hour, and scattered radiation can reach levels of 1 roentgen/hour.

Because of the low energy of the x-rays, the skin or eyes are usually the most easily damaged organs. Although exposure of the lens of the eye to large doses can result in formation of cataracts or other opacities, severe burns to the upper extremities are the most frequently reported injury. These injuries can be slow to heal. High-dose exposure can lead to ulcerations that do not heal, which may eventually result in amputation.

10.9.5 Radiation Hazards

An x-ray diffraction unit may simultaneously radiate as many as four very small beams. The beams are frequently in a horizontal plane about 4 or 5 feet above the floor. Some of the most common causes of unnecessary radiation exposure are described in Part B, Section 9 of the "Radiation Protection Program Manual."

10.9.6 Radiation Dose Limits

The standards for radiation exposure from x-ray units are the same as the standards for radioactive material. These are described in Part B, Section 10 of the "Radiation Protection Program Manual" and in 10 CFR 20.

10.9.7 Personnel-Monitoring Equipment

Appropriate personnel-monitoring devices that are sensitive to x-rays are available from the Health Physics Office. The need for these devices will be determined by the RSO after an evaluation of working conditions.

10.9.8 Health Surveillance

A preplacement medical examination must be given to all personnel new to radiation work. And an exit examination must be performed for radiation workers upon termination of employment. The nature of all examinations will be determined by the Medical Officer.

10.9.9 Identification of X-Ray Facilities

Each x-ray facility shall be located within an x-ray restricted area that is separated from the adjacent unrestricted area by a suitable barrier or installation enclosure. Specific details are described in Part B, Section 13 of the "Radiation Program Protection Manual."

10.9.10 X-Ray System Classification

X-ray systems for certain specific applications can be designed so that all possible beam paths are fully enclosed. However, operation requirements, such as frequent changes of attachments and configuration, the need to make adjustments with the x-ray beam on, and the motion of the specimen and detector over wide angular limits, may make a fully enclosed system impractical. A particular unit's mode of operation may also determine whether it is an open-beam or enclosed-beam system. In either case it must comply with the appropriate requirements in Part B, Sections 15a and 15b of the "Radiation Protection Program Manual."

10.9.11 Design Requirements

Both enclosed-beam and open-beam x-ray systems must fulfill specific requirements regarding shielding, labeling, protective and warning devices, equipment controls, location, and radiation from components such as high-voltage rectifiers. In addition, open-beam x-ray systems must fulfill requirements regarding shutters, interlocks, and coupling of the x-ray tube and collimator. These are described in detail in Part B, Section 15 of the "Radiation Protection Program Manual."

10.9.12 Operating Procedures

Operating procedures in themselves are not sufficient safeguards to guarantee personnel protection. Such protection requires the expert knowledge of all persons concerned and their cooperation in and desire to follow appropriate procedures, which are described in Part B, Section 16 of the "Radiation Protection Program Manual."

10.9.13 Repair and Alignment Procedures

Most severe injuries due to radiation exposure occur during nonroutine operations, such as repair of the system and alignment of the beam. Extreme care should be taken during these activities. Specific procedures for repair and realignment are listed in Part B, Section 17 of the "Radiation Protection Program Manual."

10.9.14 Use of Nonstandard Accessories

Any device for use with an x-ray tube shall be regarded as a nonstandard accessory unless it is a compatible component manufactured specifically to fit the equipment used. Nonstandard accessories shall not be used until procedures have been approved and a radiation survey has been performed by the RSO.

10.9.15 Other Protective Measures

Part B, Section 19 of the "Radiation Protection Program Manual" details additional protective measures applicable to those using x-ray systems.

10.9.16 Exceptions

Exceptions to the rules and regulations governing x-ray diffraction equipment may be made with the approval of the Office of Environmental Programs (OEP) in specific instances when the OEP judges the unit to be safe with these exceptions.

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Chapter 11. NON-IONIZING RADIATION

Chapter 11. NON-IONIZING RADIATION

11.1 SCOPE

This chapter establishes the procedures, policies, and responsibilities pertaining to the Non-Ionizing Radiation Program and, in particular, to laser and radiofrequency safety.

The primary purpose of the Non-Ionizing Radiation Program is to maintain and conserve the health of all involved personnel by applying acceptable standards of safety. Additionally, this program is targeted to minimize the accidental loss of or damage to research facilities and equipment. The program takes full note of the research nature of most of the work at Lewis and the attendant risks inherent in doing things never before attempted.

The American National Standard Institute's "Safe Use of Lasers" (ANSI Z136.1) is the basic standard for laser safety. As a general rule, this standard requires control measures for all lasers of Class 2 and above. In concert with this standard, Lewis Safety Permits must be sought for all such applications. Under rare circumstances, the need for a permit may be waived by the Area Safety Committee chairman and the Laser Safety Officer.

11.2 APPLICABILITY

This chapter is applicable to the Cleveland Center, Plum Brook Station, and other facilities under Lewis' cognizance.

11.3 LASER SAFETY PROGRAM RESPONSIBILITIES

The Office of Environmental Programs (OEP), of which the Laser Safety Officer (LSO) is a member, has overall responsibility for establishing and maintaining the Laser Safety Program. The OEP shall provide or otherwise make available all laser warning signs, labels, and such, as required by ANSI Z136.1 and/or the LSO.

11.3.1 Laser Safety Officer (LSO)

The LSO's responsibilities are to

(a) Act as a consultant on laser hazard evaluation and control

(b) Review all requests for Safety Permits, renewals, and modifications that involve laser operation; classify the lasers involved; and specify laser control measures, all in accordance with ANSI Z136.1

(c) Forward the names of personnel who shall require medical surveillance, along with the risk classification of each, to the Medical Director, the appropriate Area Safety Committee chairman, and the supervisor

(d) Approve protective equipment to be used for control of laser hazards, in accordance with ANSI Z136.1

(e) Ensure that all lasers carry the appropriate labels

(f) Review and approve all laser safety training for personnel and ensure its availability

(g) Establish the minimum requirements (for both training and medical surveillance) that a candidate laser operator must fulfill to be certified as a qualified laser operator

(h) Maintain records of lasers and qualified laser operators (excluding medical records)

(i) Suspend, restrict, or terminate the operation of a laser system if he/she determines that laser hazard controls are inadequate

(j) Participate with the Safety Assurance Office in the investigation of all accidents or suspected accidents involving lasers. Specifically, the LSO shall

- Recommend whether a formal Plant Accident Committee investigation should be undertaken

- Serve as an ad hoc committee member if such a committee investigation is authorized

- Issue an appropriate Unusual Incident Report if such committee action is not authorized

(k) Maintain detailed familiarity with the current edition of ANSI Z136.1

11.3.2 Area Safety Committee

Responsibilities of the cognizant Area Safety Committee are to

(a) Incorporate the requirements for laser safety as specified by the LSO into the Safety Permit and ensure compliance with them

(b) Review all Safety Permit renewal and modification requests to ensure continued compliance with the requirements for laser safety as specified by the LSO

(c) Ensure that all operators on the Qualified Operators List have met the stated requirements for becoming qualified laser operators

(d) Participate in investigating any accident that is laser related

11.3.3 Medical Director

The Medical Director shall

(a) Direct the medical surveillance program for laser personnel, in accordance with ANSI Z136.1

(b) Coordinate and schedule required medical examinations for qualified laser operators

(c) Maintain medical records for personnel who have received medical surveillance, and review and update existing records annually

(d) Forward, via electronic mail to the LSO and the Area Safety Committee chairman, the names of personnel who have received medical surveillance, within 10 days of its accomplishment

(e) Indicate to the LSO and the Area Safety Committee chairman, via electronic mail, personnel who should receive limited laser exposure or no exposure

11.3.4 Person Responsible for Permit (PRP)

The person who obtains the Safety Permit shall

(a) Provide all personnel on the project team who will work with lasers with appropriate instructions on laser hazards and their control

(b) Provide the Area Safety Committee chairman with the information necessary to ascertain that the proposed qualified laser operators have indeed been qualified

(c) Prohibit the initial operation of a laser system that is under his/her supervision, without the prior approval of the LSO and the issuance of a Safety Permit

(d) Immediately notify the LSO, the Area Safety Committee chairman, and the Chief of the Safety Assurance Office of any known or suspected accident resulting from laser operation under his/her supervision

(e) Forward to the LSO a copy of Form NASA-C-580, Qualified Operators List, stating the names of personnel proposed to be included with the Safety Permit as qualified laser operators (This is in addition to the normal routing of this form.)

(f) Keep the Qualified Operators List current

(g) Notify the LSO of the need to qualify a laser operator. This should be done at least 3 weeks before the proposed qualified laser operator arrives at Lewis, if qualification must be done quickly. Examples of such cases are summer personnel, cooperative students, and any temporary personnel whose duration at Lewis is expected to be less than 10 times the mean time for qualification.

(h) Notify the LSO and the Area Safety Committee chairman of modifications to previously authorized laser systems. The modified system shall not be operated without prior approval of these two people, and the modification may require a change to the Safety Permit. Modifications, here, refer to changes that significantly alter the safety restrictions per ANSI Z136.1.

(i) Submit to the LSO all proposed plans for laser installations, for review of laser safety hazards

11.3.5 Laser Operator

The laser operator shall

(a) Under no circumstance operate a laser system without a current Safety Permit that covers that specific laser

(b) Not operate a laser system that does not satisfy all requirements of the authorizing Safety Permit

(c) Become familiar with ANSI Z136.1, with particular emphasis on the laser hazards and their control for all laser systems he/she will operate

11.4 PROGRAM REQUIREMENTS

11.4.1 Authorization

Only those persons listed as qualified laser operators on the pertinent Qualified Operators List (or persons being trained by a qualified laser operator) shall operate a laser system. The Qualified Operators List shall accompany the Safety Permit Request when application is made for a new permit, or it may be submitted by itself when the Qualified Operators List is revised.

Authorization shall be granted upon signature of the Area Safety Committee chairman.

11.4.2 Laser Classification

Laser classification is based on the capability of the laser or laser system to injure personnel. Accordingly, all lasers shall be classified and appropriately labeled in accordance with criteria specified in ANSI Z136.1.

11.4.3 Protective Equipment

Protective equipment shall be as specified in ANSI Z136.1

11.4.4 Accidents and Incidents

Personnel involved in known or suspected accidents involving laser operation shall immediately notify the supervisor of the facility and the person responsible for the Safety Permit. Emergency procedures listed in LMI 1743.1 are to be followed. The supervisor of the facility shall also notify the LSO and the Area Safety Committee chairman. The LSO shall conduct a preliminary investigation of the incident per Section 11.3.1(j) of this chapter, consult with the Medical Director when necessary, and issue an Unusual Incident Report when required.

11.4.5 Visitors

Visitors to laser facilities are defined as all persons other than the authorized laser operators for the facility. Visitors shall be under the direct supervision of at least one of the authorized laser operators. Visitors shall wear proper protective equipment whenever Maximum Permissible Exposure (MPE) levels may be exceeded.

11.4.6 Maximum Permissible Exposure

MPE values are established at levels that are below known hazardous levels. No person shall intentionally exceed, or cause others to exceed, MPE values. MPE values may be obtained from ANSI Z136.1.

11.4.7 Control Measures

Control measures shall conform to ANSI Z136.1.

11.5 MEDICAL SURVEILLANCE

Medical surveillance shall conform to ANSI Z136.1.

11.6 RADIATION INTERFERENCE

The operation of **industrial, scientific, medical, and other equipment** generating radiofrequency energy may cause interference with authorized radio, radio-navigation, and telecommunication systems. If this occurs, immediate steps shall be taken to remedy the interference.

Equipment generating radiofrequency energy between 30 hertz and 30,000 megahertz is regarded as a cause of interference unless such equipment is provided with power line filters, shielding, bonding, and grounding to prevent the emitted energy, including spurious and harmonic, from exceeding the limits established in Chapter 7 of the "Manual of Regulations and Procedures for Federal Radio Frequency Management."

The project operator shall ensure that research equipment radiation levels are below the interference potentials stated herein. The Lewis Radiofrequency Manager shall be contacted by the project operator prior to procurement and operation of new equipment capable of generating radiofrequencies.

11.7 RADIOFREQUENCY HEALTH HAZARDS

11.7.1 General

Health hazards due to improper use of high-power radiofrequency (RF) generators, such as radar equipment, laboratory microwave setups, microwave diathermy equipment, and so on, are possible.

11.7.2 Critical Frequency Ranges

The equipment that causes most physical damage is in the frequency range from about 200 to 10,000 megahertz. Frequencies above 1,000 megahertz are called "microwaves."

Conventional diathermy equipment operates at about 300 megahertz and microwave diathermy equipment operates at 2,450 megahertz.

11.7.3 Biological Effects

The health hazard is primarily due to microwaves heating the body tissue sufficient to cause damage.

The depth of RF penetration in body tissue varies inversely with frequency such that above 10,000 megahertz the incident power is either reflected or almost entirely absorbed in the skin. Between about 1,000 and 3,000 megahertz, the incident power is absorbed both in the skin and in the deeper tissues, but below about 1,000 megahertz the deeper tissues are affected, as in conventional diathermy.

Two organs are most seriously affected by excess RF radiation: (l) the eyes, which can be permanently damaged by the formation of cataracts and (2) the testicles, which can be temporarily damaged, thereby causing temporary sterilization.

11.7.4 Permissible Exposure Levels

The following table indicates radiation protection guides (RPG's) for incident electromagnetic energy of frequencies from 10 megahertz to 100 gigahertz:

Power density	Exposure limit
Density $\leq$ 10 mW/cm^2	Total continuous exposure $\leq$ 8 hours/workday
10 mW/cm^2 > density $\leq$ 25 mW/cm^2	Total intermittent exposure $\leq$ 10 minutes/ 60-minute period during 8-hour workday
Density > 25 mW/cm^2	None permitted

The preceding values are appropriate for moderate environments. Under conditions of moderate to severe heat stress, the exposure should be appropriately reduced. Under conditions of intense cold, higher exposure may be appropriate after careful consideration of the individual situation. However, any deviation from the RPG's established in this chapter requires prior written approval from the Office of Environmental Programs.

11.7.5 Precautions

The following precautions include guidelines to protect personnel from overexposure to RF radiation. Other precautions and procedures may be established and included in the Rig Operating Safety Permit.

(a) Do not look into waveguide horns, antennas, or open waveguides when any microwave equipment is on.

(b) Do not remain in the presence of high-frequency radiation in excess of 25 milliwatts/ square centimeter.

(c) Ask the Office of Environmental Programs to measure and evaluate the x-ray hazard posed by all equipment with voltages in excess of 15,000 volts.

(d) Do not wear metal jewelry or eye glasses near electronic equipment radiating RF energy, even though the level is below the established safe value of 10 milliwatts/ square centimeter, because the radiated energy may be focused or concentrated.

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Chapter 12. AVIATION SAFETY

Chapter 12. AVIATION SAFETY

12.1 SCOPE

The Lewis Research Center Aviation Safety Program establishes policy, responsibilities, and guidelines, and sets forth procedures and requirements to ensure the safety of personnel and equipment and the safe conduct of aviation functions and activities. This Program is tailored to the Lewis organization and its aircraft mission. The Lewis aviation safety plan follows the guidelines set forth in Chapter 7 of the "NASA Basic Safety Manual" (NHB 1700.1, Vol. 1) and the NMI 7910 series. Other documents referenced are listed in Section 12.9.

12.2 POLICY

Safety is a line-management responsibility; therefore, this Program provides line management oversight of Lewis aviation functions and activities. Aircraft operations shall be conducted under the cognizance of the Lewis Safety Organization, and no aircraft or experiment shall be committed to flight without a valid Safety Permit or appropriate safety approval. It is the intent of this Program to comply with all applicable NASA directives, Federal Aviation Regulations, and other governing instructions.

12.3 RESPONSIBILITIES/FUNCTIONS

Although aviation safety is everyone's concern, the primary responsibility rests with the Center Director and the Flight Operations Manager.

To ensure effective implementation of the Lewis Aviation Safety Program, responsibilities/functions are assigned as follows:

12.3.1 Center Director

The Center Director is responsible for ensuring the safe operation of all aircraft assigned to Lewis and for establishing and implementing an aviation safety program. In part, the Director will ensure that

(a) Aviation safety is an integral part of the overall Lewis Safety Program.

(b) Lewis complies with all NASA aircraft management policies and directives as established by higher authority

(c) An appropriate aircraft operations staff is in place and is properly organized, equipped, and trained to provide for the conduct of safe and effective flight operations

(d) The aircraft operations organization has an established aviation safety program commensurate with the level and type of flight activity, and that appropriate oversight is provided

(e) The aircraft operations organization supports the NASA Intercenter Aircraft Operations Panel (IAOP), which, in turn, supports the Associate Administrator for Management (Code N) in the development of guidance on operational aspects of aviation safety; the Associate Administrator for Safety and Mission Quality (Code Q) in the development of overall aviation safety policies; and the Aircraft Management Office (Code NIF) in establishing review teams to periodically review all aspects of aircraft operations at NASA installations

12.3.2 Aircraft Operations Branch Chief

The Chief of the Aircraft Operations Branch is the designated Flight Operations Manager. Under the cognizance of the Center Director, the Chief is responsible for safe operation of all assigned Lewis aircraft. In particular, he/she will ensure that the following elements and functions are a part of the Aviation Safety Program:

(a) A flight operations handbook outlining procedures, requirements, and guidelines for conducting safe flight operations ("Aircraft Operations Manual")

(b) An organization that is actively conducting airworthiness reviews for research aircraft or projects, using a multidisciplinary, system-type approach and functioning independent of line management, and that these reviews are documented ("Research Flight Operations and Airworthiness Procedures," LHB 7910.2)

(c) A configuration control system to ensure real-time monitoring and documentation

(d) Training for initial checkout and current requirements

12.3.3 Aircraft Maintenance Branch Chief

The Chief of the Aircraft Maintenance Branch, under the cognizance of management authority, is responsible for maintaining all Lewis aircraft and for ensuring compliance with the provisions of this chapter. The Chief also serves as a member of the Area I Safety Committee.

12.3.4 Aviation Safety Officer

The Aviation Safety Officer (ASO) is a Lewis research pilot designated by the Executive Safety Board chairman. As such, the ASO is the Center's focal point on flight research/flight experiment airworthiness and mishap response. Although the Chief of the Aircraft Operations Branch has direct responsibility for flight safety, should the need arise, the ASO has unrestricted access on matters affecting flight safety to the Executive Safety Board chairman. In this capacity, the ASO has the authority to shut down any operation or activity in question until an appropriate review can be conducted (see LHB 7910.2 and the "Aircraft Operations Manual").

12.3.5 Operations Safety Manager

The Operations Safety Manager (OSM) is a Lewis pilot designated by the Chief of the Aircraft Operations Branch to serve as the focal point for ensuring safe flight/ground operations procedures and practices for Lewis aircraft; the OSM's duties/ responsibilities are detailed in LHB 7910.2. Specifically, the OSM has the authority to shut down any operation or activity in question until an appropriate review can be conducted.

12.3.6 Pilot In Command

A Lewis aircraft Pilot In Command (PIC) has the final responsibility and authority to ensure the safe operation of the aircraft and the safety of passengers or crew members who may be involved in research activities on board the aircraft.

12.3.7 Airworthiness and Configuration Control Manager

The Airworthiness and Configuration Control Manager (ACCM) is responsible for coordinating and documenting airworthiness reviews and for maintaining documentation necessary to completely define an aircraft's immediate configuration (LHB 7910.2 and "Aircraft Operations Manual").

12.3.8 Area 1 Safety Committee

The Area 1 Safety Committee (A1SC), as established in Chapter 1 of the Lewis Safety Manual, reviews operations of and R&D modifications to aircraft operated by Lewis, as well as experiments placed on these aircraft. The A1SC is the sole authority for issuing Lewis aircraft/flight experiment Safety Permits. The hazard analysis and airworthiness review process used by the A1SC is described in further detail in LHB 7910.2 and the "Aircraft Operations Manual."

12.3.9 Airworthiness Review Panel

The Airworthiness Review Panel (ARP), appointed by the Director of Aeronautics (LMI 7910.1), conducts independent technical reviews of all proposed R&D modifications/flight experiments and reports its findings to the Area 1 Safety Committee. The hazard analysis and airworthiness review process is described in further detail in LHB 7910.2.

12.4 PROPOSED PROJECT/EXPERIMENT APPROVAL

To enhance safety and ensure management overview at an early stage, any Lewis division proposing an airborne project/flight experiment shall prepare a memorandum detailing the principal objectives and specific requirements. This memorandum will be routed for operational approval to the Director of Aeronautics. For non-Lewis-originated experiments, a Space Act Agreement (formerly a Memorandum of Understanding) will be initiated by the proposing organization and sent to the Center Director for signature. The signing authority for the proposing organization should be at least the same managerial level as the Center Director (LHB 7910.2).

12.5 AIRWORTHINESS AND FLIGHT EXPERIMENT REVIEWS

12.5.1 Purpose

The purpose of these reviews is to assure management that the risks to persons and property are minimized and that the operational plans for conducting a mission/program have been approved. Formal review requirements must be commensurate with the significance of the mission/project and the risk involved. Dedicated review organizations (Airworthiness Review Panel and the Area 1 Safety Committee) conduct these reviews independent of line management. This review process is a multi-disciplinary, system-like approach that includes appropriate safety analysis and risk assessment. Such reviews are formally conducted and fully documented. They are applicable to all aircraft modifications and flight experiments. The process and details can be found in LHB 7910.2.

12.5.2 Aviation Safety Officer

The Aviation Safety Officer plays an essential part in these reviews, reviewing and evaluating proposed modifications to the aircraft and experiments to be flown thereon, and reviewing and evaluating flight profiles, operating procedures, training and performance requirements, and any required aircraft operations limitations. The ASO also reviews the airworthiness of flight work orders, in some cases giving signature approval, and provides technical guidance on safety aspects of flight activities.

12.6 OPERATIONS SAFETY PLAN

The Operations Safety Plan is designed to ensure a high level of operational safety awareness in day-to-day aircraft operations among flight and ground crews. It is implemented by the Operations Safety Manager, who ensures that relevant safety material is read or used by the people that are involved in flight activities. Additional elements of this plan can be found in the "Aircraft Operations Manual."

12.7 CONFIGURATION CONTROL PLAN

Configuration control is a vital part of any aviation safety program. The Airworthiness and Configuration Control Manager is responsible for coordinating this plan. A very important aspect of this system is the flight work order document. The process and details of this plan, as well as the flight work order procedures, can be found in LHB 7910.2 and the "Aircraft Operations Manual."

12.8 MEDICAL CLEARANCE AND PHYSIOLOGICAL REQUIREMENTS

Medical clearance and physiological requirements shall be in accordance with NMI 7910.3, NHB 7920.3, and the "Aircraft Operations Manual." In general, all Lewis pilots are required to obtain first-class medical certificates annually. Flight crew members and research personnel require third-class medical certificates. Physiological, EGRESS, and life-support training shall be accomplished as required.

Training and certification records shall be kept in an Aircraft Operations Branch file (per the "Aircraft Operations Manual").

12.9 BIBLIOGRAPHY

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Chapter 13. LABORATORY SAFETY

Chapter 13. LABORATORY SAFETY

13.1 SCOPE

This chapter is organized to describe the policies, responsibilities, and general safety procedures for the operation of laboratories at the Lewis Research Center. Specific details regarding laboratory safety procedures can be found in a number of references, including Chapter 4 of this Manual, the OSHA Standards (29 CFR 1910), and the "CRC Handbook of Laboratory Safety."

13.2 DEFINITIONS

A comprehensive list of definitions related to laboratory safety can be found in the "Lewis Material Safety Data Sheet Dictionary."

13.3 APPLICABILITY

This chapter is applicable to all personnel of the Lewis Research Center, both at Cleveland and at Plum Brook Station.

13.4 RESPONSIBILITIES

Although the Executive Safety Board, the Area Safety Committees, the Environmental Pollution Control Board, and the Office of Environmental Programs are broadly responsible for ensuring a safe working environment, the following bear specific responsibilities that affect laboratory safety.

13.4.1 Supervisors

Laboratory supervisors are responsible for maintaining their operations in accordance with the requirements of this chapter and the Lewis Safety Program.

13.4.2 Employees

All employees at the Lewis Research Center Cleveland facilities and Plum Brook Station who supervise, occupy, or enter the laboratories are responsible for understanding and conforming to the policies, safe practices, and provisions of this chapter.

13.5 BASIC LABORATORY SAFETY GUIDELINES

The objective of the Lewis Safety Program is to provide Lewis employees with a workplace free from environmental and occupational hazards. Detailed laboratory safety requirements are found in the OSHA Standards, 29 CFR 1910. The following are basic rules for laboratory safety:

(a) Wear eye protection at all times in the laboratories and in areas where chemicals are stored and handled.

(b) Know the hazards of chemicals used. Obtain Material Safety Data Sheets for each chemical and keep them current.

(c) Do not eat, drink, or smoke in the laboratories.

(d) Never pipette by mouth.

(e) Wear appropriate clothing, including a protective apron or laboratory coat.

(f) Transport containers of acids, alkalies, flammable or combustible substances, or corrosive chemicals only if they are encased in plastic or in carriers to protect them from breakage and to limit their spread in case of leaks.

(g) Never work in the laboratory alone; others should be present in the laboratory area.

(h) Require visitors to follow the same rules as laboratory workers.

13.6 SPECIFIC SAFETY GUIDELINES

13.6.1 Housekeeping

In general, the workplace shall be kept neat, clean, and uncluttered. In order to accomplish this

(a) Avoid unnecessary hazards by keeping drawers and cabinets closed while you work.

(b) Keep aisles free of obstructions such as boxes, chairs, and waste receptacles.

(c) Pick up from the floor such items as ice, glass beads, stoppers, glass rods, and other small items, and wipe up wet spots.

(d) Dispose of chemical waste by recommended procedures (see Ch. 4).

13.6.2 Exitways

Furniture and equipment shall not be placed in corridors and aisles. In case of emergency, people required to exit through such paths, possibly in darkness, would encounter numerous projections and tripping hazards. In addition, during rescue operations, the fire department must be able to maneuver stretchers and other emergency equipment through corridors and aisles.

Each employee should check frequently to be sure there are two exit paths from his/her workstation to the outside of the building.

13.6.3 Bottle Disposal

All empty bottles that held chemicals should be thoroughly rinsed before disposal. Properly rinsed bottles minimize the hazards associated with breaking a bottle during the disposal process.

13.6.4 Ovens

No combustible material may be stored in any drying oven. Every oven should be equipped with a backup thermostat or temperature-controlling device that will shut down the oven or control the unit should the primary controller fail. More detailed oven safety considerations are found in the "CRC Handbook of Laboratory Safety."

13.6.5 Refrigerators

Refrigerators constitute a unique hazard because explosions may occur when volatile or unstable chemicals are stored in them. Only explosion-proof refrigerators may be used for chemical storage, and they should be wired directly to the power source. Domestic refrigerators should not be used to store chemicals, even when they have been modified to eliminate open electrical contacts inside the storage cabinet, because the motor and other electrical parts on the exterior can ignite flammable vapors in the room.

Food storage in refrigerators used for chemicals is prohibited.

13.6.6 Centrifuges

Users of centrifuges must be sure to balance the centrifuge each time it is used. Bench-top centrifuges should be securely anchored. Important items to check are the following:

(a) Is the wall thick enough to shield against accidental flyaway objects?

(b) Are there wheel brakes to prevent the centrifuge from "walking"?

(c) Is the centrifuge electrically grounded?

(d) Is there a disconnect switch to shut off the rotor if the top is inadvertently opened?

(e) Is the centrifuge located where it will not cause vibration in other equipment?

13.6.7 Fume Hoods

All operations involving flammable, toxic, noxious, or otherwise hazardous solids, liquids, vapors, or gases should be conducted, as much as possible, in a fume hood. Operations involving perchloric acid should be carried out only in special perchloric acid hoods. The air slots in hoods must not be blocked, and operations should be carried out as far into a hood as practical, but at least 6 inches from the front. The sash should be pulled as low as work permits.

Hoods should not be used as a means to evaporate waste chemicals. Chemicals should not be stored in hoods, since they may block air slots and crowd the available working area.

13.6.8 Chemical Storage

Chemicals should be separated into compatible chemical groups and stored in stable and secure storage facilities. Minimal quantities of flammable liquids should be stored in the laboratory. Detailed chemical storage requirements, including chemical incompatibilities, are described in the "CRC Handbook of Laboratory Safety."

13.6.9 Container Labels

All chemicals, including reagents and compounds prepared at Lewis, must be kept in clearly labeled containers. Prepared reagents must be labeled with their chemical composition, concentration, date of preparation, and name of the person who prepared the reagent. All chemicals received for laboratory use should be labeled with the date received. Detailed labeling requirements are described in Chapter 4 of this Manual.

13.6.10 Compressed Gases

Compressed gases are most frequently used in standard cylinders of approximately 3,000 cubic feet. These gas cylinders are filled to high pressures, up to 2,500 pounds per square inch gauge pressure. The smallest sized cylinder that is adequate for the job should be routinely used, particularly for hazardous gases. All users should know the properties of the gas being handled, including factors such as toxicity and flammability. The following rules are recommended for safe use of compressed gases:

(a) Handle cylinders of compressed gases as high-energy sources and potential explosives.

(b) When storing or transporting cylinders, make sure the protective cap is in place to protect the valve stem.

(c) When moving large cylinders, use a hand truck with a safety chain, or strap the cylinder in place. Never roll, slide, or drag the cylinder to move it, even for a short distance.

(d) Do not expose cylinders to temperatures higher than approximately 50 °C. Some rupture devices on cylinders will release at about 65 °C.

(e) Make sure that the contents of the cylinder are properly identified. The color of a cylinder is not a reliable indicator of the contents.

(f) Never lubricate, modify, force, or tamper with a cylinder valve or any relief valve.

(g) Use cylinders of toxic, flammable, or reactive gases in fume hoods only. Store them in appropriately ventilated cabinets.

(h) Use a chain or strap to secure cylinders in laboratories to a wall, bench, or other firm support. The securing device must support the upper half of the cylinder to prevent tipping.

(i) Do not extinguish the flame of a highly combustible gas until the source of gas has been shut off; otherwise, the gas can re-ignite and cause an explosion.

(j) Use the proper regulator to control pressure and flow rate; do not use adaptors. The Compressed Gas Association has developed various cylinder valve outlet connectors for different families of gases; this prevents the interchange of regulating and control equipment between incompatible gases.

(k) Never lubricate a regulator. Oil or grease on the high-pressure side of a cylinder of oxygen, chlorine, or an oxidizing agent can lead to an explosion. For oxygen cylinders, use new regulators or a regulator that is currently on an oxygen cylinder.

(l) Completely release the regulator pressure adjustment valve before opening the cylinder valve; then open the cylinder valve slowly. Never use a hammer or oversized wrench to force a valve that is stuck.

(m) Always use a trap or check valve to prevent chemicals from being back-siphoned into the cylinder.

(n) When the pressure in a cylinder has been reduced to approximately 5 psig, attach an "Empty" label to the cylinder and replace it with a fresh cylinder. Never bleed a cylinder completely empty; leave a slight pressure to keep contaminants out.

(o) Always wear safety glasses when handling and using compressed gases.

13.6.11 Glassware

Borosilicate glassware is recommended for all laboratory operations except those in which ultraviolet or other light sources are used. The only soft glass in the laboratory should be reagent bottles, measuring equipment, stirring rods, and tubing. Broken glassware should not be thrown in the regular trash, since it can cause injury to janitorial personnel. A detailed description of glassware considerations can be found in the "CRC Handbook of Laboratory Safety."

13.6.12 Blade and Hypodermic Needle Disposal

Razor or scalpel blades must not be thrown in the trash unless precautions have been taken to ensure that they cannot cut someone who is handling the waste. A single blade should be wrapped in heavy tape prior to disposal. When large numbers of blades are involved, place them in a sealed container such as a metal can.

Keep unused syringes and hypodermic needles in a locked drawer or cabinet. Place hypodermic needles used for other than biological purposes in a can for disposal. Scalpel blades and hypodermic needles that have been used on biological samples must be disposed of differently because they are potentially infectious. Do not bend, break, or otherwise manipulate these instruments since this increases the chance of accidental puncture. Place such instruments in rigid, puncture-proof containers and seal the container prior to disposal.

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Chapter 14. SHOP SAFETY

Chapter 14. SHOP SAFETY

14.1 SCOPE

This chapter sets forth the Lewis Research Center shop safety policy and assigns responsibilities for implementation and enforcement.

14.2 APPLICABILITY

This chapter is applicable to the Cleveland and Plum Brook facilities, and any other facilities under the Lewis Research Center cognizance.

14.3 POLICY

Lewis Research Center will provide the proper equipment, facilities, safety rules, and procedures necessary for safe working conditions. To achieve and maintain this safe working environment, the cooperation of every member of the staff is essential. The staff is responsible for using the equipment and facilities in a safe, approved manner and for suggesting improvements and/or modifications to them, thereby contributing to an effective shop safety program.

Safety regulations cannot cover every situation. If conditions are not covered in this chapter or if deviations from these procedures become necessary, the Safety Assurance Office shall be consulted prior to any work being performed.

Safety equipment issued by NASA remains the property of the U.S. Government and must be returned on demand. Reimbursement from the employee for loss of equipment may be required at the discretion of the Government.

14.4 RESPONSIBILITIES

14.4.1 Area Safety Committees

Although the Center Director, the Executive Safety Board, and the Safety Assurance Office are responsible for setting policies and procedures and for assisting in the implementation of such policies, it is the Area Safety Committees who are responsible within their assigned areas for ensuring implementation of the Occupational Safety and Health Act and other established instructions and procedures.

14.4.2 Supervisors

Supervisors are responsible for enforcing safety rules and regulations. They shall maintain safe working conditions and shall immediately correct recognized unsafe conditions affecting personnel and facilities under their jurisdiction. Each supervisor must ensure that all personnel under his/her supervision are aware of the applicable safety procedures, building regulations, and the requirements of this Manual.

14.4.3 Employees

Each employee, as a condition of employment, is responsible for following all safety rules, regulations, and practices. Employees who violate safety rules are subject to disciplinary action.

14.5 REQUIREMENTS

14.5.1 Basic Shop Safety Rules

(a) All employees must know and comply with safety rules and regulations governing required protection and conduct in the areas in which they work.

(b) All employees are expected and encouraged to ask questions to remove any doubt about the safe way to perform any job.

(c) No employee may make alterations or perform major repairs on any safety equipment unless specifically authorized by his/her supervisor.

(d) Machines and equipment shall be operated only by personnel specifically qualified to do so.

(e) All necessary precautions shall be taken so that tools and materials are not, by reason of location or use, a hazard to others.

(f) Spilled materials shall be cleaned up properly, promptly, and completely, whether liquid or solid. If immediate cleanup is not possible, the area must be barricaded to prevent accidents.

(g) All tools and excess materials shall be removed and properly disposed of after a job is completed.

(h) All air- or electrically-driven machines or tools shall be completely stopped when (1) the machine is being inspected, (2) work is being discussed with others, (3) the equipment is left unattended (except for machines designed for unattended operation), or (4) accessories or parts are being changed.

(i) No drum shall be pressurized without prior approval of the Area Supervisor, who shall be advised by the Safety Assurance Office about the specific system and its provisions for fail-safe protection against over-pressurization.

(j) Employees shall not attempt to lift heavy or bulky objects that are beyond their capability. Size up the load and get help if needed. Keep your back vertical and knees bent; lift with your leg muscles, keeping the load close to your body.

(k) Employees shall not carry sharp objects in their pockets or clothing.

(l) Employees shall use approved containers or devices for transporting material or equipment.

(m) Aisles and walkways should be marked and used at all times. Short cuts through roped off or working areas, across ditches, or over rough grounds are prohibited.

(n) Walking under work stands or under suspended loads must be avoided.

(o) Makeshift devices shall not be used instead of ladders for reaching heights.

(p) Employees must use both hands when climbing or descending ladders.

(q) Desk drawers, cabinet doors, and locker doors shall be kept closed when not in use.

(r) Employees shall walk up or down stairs one at a time, using the hand rail.

(s) Employees shall walk carefully and be alert at all times. Running is not permitted except to avoid dangers.

(t) Horseplay is prohibited.

(u) Every accident or near miss shall immediately be reported to the supervisor, whether or not anyone is injured.

(v) Do not remove, displace, damage, destroy, or carry off from any location in the plant any safety device, safeguard, notice, or warning furnished for use there.

(w) No employee shall interfere with any method or process adopted for the protection of any employee, including him/herself.

(x) Posted work areas may not be entered without proper authorization and an understanding of the special safety rules of the area.

(y) Do not block aisles, passageways, corridors, fire lanes, or fire and emergency equipment.

(z) When driving, observe all local traffic rules and regulations, obey displayed warnings, and defer to emergency vehicles and vehicles used for transporting dangerous materials. Speeding will not be tolerated (see Ch. 19, Vehicle and Pedestrian Safety).

(aa) Do not smoke or use open flames in posted areas or in any area where flammable or explosive materials are being used, stored, or handled, whether posted or not.

(bb) No unauthorized person shall make electrical or mechanical repairs on Government-owned equipment.

(cc) All tools furnished to or owned by an employee are subject to inspections and approval by the Safety Officer, to ensure that the design, condition, and construction allow the work to be performed safely.

(dd) Only authorized personnel shall move, rearrange, and repair office equipment.

14.5.2 Personal Safety

General rules.—The following regulations are for your protection:

(a) Do not work if you are ill, since your condition may cause an accident and injury to yourself or others.

(b) Sleeping on the job is prohibited.

(c) The possession or use of alcoholic beverages on Government premises is prohibited; no person shall report for duty or perform duties while under the influence of intoxicants.

(d) The use of narcotics, tranquilizers, or barbiturates by Government personnel while at work is prohibited without the cognizance of the Office of Health Services.

(e) Wearing of protective gear, such as hand protection, foot protection, eye protection, head protection, and respirators, is mandatory in areas and operations where specified.

(f) Clothing and footwear that is appropriate for the work to be performed shall be worn. Jewelry, loose sleeves, ties, lapels, cuffs, tags, or other loose objects shall not be worn near moving machinery. When employees with long hair work with rotating machinery, they shall wear suitable headgear that completely confines the hair. Safety shoes shall be worn where mechanical or manual work is done and where chemicals or other materials are stored or handled. Slippers, canvas shoes, sandals, and shoes with open toes or high heels shall not be worn in such locations.

(g) Contact lenses shall not be used. Prescription safety glasses must meet Federal specifications for safety.

(h) The use of volatile or flammable chemicals, such as duplicating fluid, trichloroethane, gasoline, or paint thinner, as a skin cleansing agent is prohibited; any use of carbon tetrachloride is prohibited unless specifically approved by the Safety Assurance Office.

Protective footwear.—Designated safety shoes are to be worn in areas where the type of work performed could be hazardous to the unprotected feet of the worker.

Footwear that is defective to the extent that its ordinary use creates the possibility of foot injury shall not be worn. Defective is defined as, but not limited to, footwear that has loose, broken, or missing parts which could cause the person to slip, trip, fall, or be exposed to falling substances that would cause injury.

Personnel working in areas where there is a potential for exposure to flammable or explosive hazards shall not wear metal cleats or other spark-producing devices on their footwear.

The Safety Assurance Office will issue special footwear requirements for contractor personnel if necessary. It shall be the contractor's responsibility to furnish the special footwear to their personnel unless otherwise noted in the contract.

Protective headwear.—It is the policy of the Lewis Research Center to minimize the requirements for protective headwear in buildings and/or processes by providing well-protected, overhead work platforms and equipment with special safety design features, guards, and protective devices.

In specific areas or operations where it is not practicable to eliminate the hazards of head injury, head protection will be required and so designated.

Hard hats (or helmets) are necessary protection where there are hazards of bumping one's head or having it struck, of contacting high voltage equipment, or of having harmful materials fall on the head. Hard hats help prevent serious injuries from all of these causes, and even if the hat dents or shatters, it still takes the force out of the blow. Hard hats offer protection in four ways: (1) the hard shell resists and reflects the blow; (2) the impact is distributed over a large area; (3) the hat suspension acts as a shock absorber; and (4) the hard hat saves the scalp, face, and neck from the results of overhead spills of acids, chemicals, or hot liquids.

Protective headwear may be of two types: helmets with a full brim, and helmets with no brim, but perhaps with a peak. Hats with **full brims** give protection to the face, temples, and sides of the head, whereas hats that are **brimless** work well in confined spaces. Both types of hard hats shall be equipped with a suspension consisting of an internal cradle (crown, straps, and sweatband). And both types of hard hats must be properly adjusted to the wearer's head. There should be at least 1-1/4 inches clearance between the top of the wearer's head and the inside shell of the hat.

There are three different classes of hard hats, according to ANSI Z89.1: Class A, for general service (2,200 volts); Class B, for high voltage protection (20,000 volts); and Class C, for limited service (0 volts).

During escorted tours, the Building Manager may waive the hard hat requirements for visitors and workers for the duration of the tour. For unescorted or transient visitors, the supervisor having cognizance over a hard-hat area is to provide the necessary hard hats.

Responsibilities of the supervisor: It is the responsibility of the unit supervisor to provide for and ensure that

(a) Entrances to hazard areas are clearly posted with caution signs worded, "HARD HAT AREA"

(b) Hard hats are worn by everyone in designated areas or for a designated operation

(c) A regular schedule of hard-hat inspections is established and maintained, and that any hard-hat suspension which has been subjected to an impact is removed from service

(d) Hard-hat stations to store, clean, and sanitize hard hats are established and maintained, with locations at entrances to designated hazardous areas if possible

(e) Temporary requirements are imposed for the wearing of hard hats for operations of an infrequent nature, such as working in the immediate vicinity of overhead construction or modification work, and entry into pits or unprotected areas

(f) All workers are trained in the care and use of hard hats

Responsibilities of the Building Manager: It is the responsibility of the Building Manager to

(a) Ensure that all elevated platform work areas (heights greater than 10 feet) are equipped with toe-boards, and that workbenches in such areas are equipped with backboards if it is possible for tools or material to fall to a lower level

(b) Prevent the storage or hanging of items on overhead platforms or handrails where such items could be dislodged and fall to a lower level

Responsibilities of the Logistics Management Division: The Logistics Management Division is responsible for issuing and maintaining a ready supply of

(a) Hard hats

(b) Suspension replacement parts, such as crown straps, suspension harnesses, and headbands

(c) Accessories such as chin straps, nape straps, winter liners, and face shields

(d) Two-way sanitizer and deodorizer for use as a disinfectant

(e) Poly bags for the storage of hard hats

Responsibilities of the user: It is the responsibility of the user to ensure the care of the hard hat by adhering to the following:

(a) Keep the hard hat free from scratches and abrasives. Do not engrave initials on hard hats; this destroys the integrity of the shell.

(b) Ensure that hard hats are maintained in a clean condition at all times. Wipe dust, dirt, and moisture from hats, suspensions, and sweatbands before storing. (When the hats are supplied for general use at a specific location, sanitizing materials will be supplied at that location.)

(c) When the hard hat is not in use, place it in a poly bag and store it on a special rack or in the designated area. Do not store it in sunlight.

(d) Participate in regularly scheduled hard-hat inspections.

(e) Use the hard hat only as intended; do not drop, throw, or abuse it.

14.5.3 Safe Use of Tools and Equipment

Approved tooling and equipment shall be used at the Lewis Research Center. Defective tooling or equipment must never be used. Such equipment must be reported immediately to the supervisor so that it can be repaired or replaced.

General rules.—The following are requirements for safe use of tools and equipment:

(a) Installation, alterations, or repairs to or substitution of tooling and equipment is to be accomplished only by personnel authorized by the supervisor.

(b) No makeshift tools or short-cut methods may be used unless authorized by the Area Supervisor.

(c) All guards must be in place before a machine is started.

(d) Equipment subject to periodic inspection and/or test shall not be used until such inspection or test has been verified as accomplished for the current period.

(e) Safety switches or devices shall not be blocked, tampered with, or altered in any manner.

(f) Unauthorized use of wood-working, metal-working, and other powered tools and equipment is prohibited.

(g) No equipment or machine shall be used if it has been "tagged" out of service. Switches that are "tagged" frequently control machines on which men are making repairs, and their lives may be endangered should the machine be started. (See Ch. 9).

(h) Equipment and tools assigned to buildings are to be kept in a designated storage place when not in use.

(i) Before any contaminated equipment or components may be shipped to outside vendors or to any shop for maintenance, repairs, or rework of any kind, a thorough inspection shall be made by the authorized industrial hygienist or health physicist, who will affix the proper decontamination certificate in accordance with the existing decontamination procedure.

Hand tools.—Only tools that are in **good** condition shall be used in operations. They shall be properly cleaned after use, and cutting tools shall be kept sharp.

Do not carry tools in your pockets. They shall be carried in a tool kit or in hand in such a manner as to prevent injury by stabbing, dropping, pinching, and the like. Some rules for specific tools follow.

Hammers: Before using a hammer, check the head for a tight fit. If the hammer has a cracked head or a loose or cracked handle, return it to the tool crib for replacement. Hammers that have burrs, loose chips, or signs of mushrooming shall not be used.

Wrenches: Use the correct wrench for the job to be done. Pull rather than push on the handle of the wrench. Do not place extensions on wrench handles for more leverage; use the proper sized wrench.

Knives: Keep your hands and the knife handles clean, dry, and free of grease.

Do not place knives on shelves or table edges where they might fall; keep the blade in a sheath when the knife is not in use.

Pliers: Wear eye protection when using pliers to clip wire ends. Hold the wire and pliers so that the ends, when snipped, are directed towards the ground.

Equipment.—Other types of equipment and the rules that apply are as follows:

(a) All blowers or exhaust equipment must be operating when work requiring their use is performed.

(b) Propellant and oxidizer equipment shall always be grounded prior to actual firing. It shall be the responsibility of the supervisor to ensure that all ground straps are in a good state of repair and that they are used properly and used only for the purpose intended.

(c) No material may be attached to, or suspended from, fire lines or sprinkler and deluge systems.

(d) All auxiliary lighting equipment brought into propellant-processing buildings for temporary use by operators or maintenance personnel shall be explosive-proof. Exceptions to this rule require specific approval from the Safety Assurance Office.

(e) As part of the grounding program, consistent with 29 CFR 1910.304(b), all shop supervisors are required to have qualified personnel conduct a quarterly electrical inspection and operational check of all portable shop equipment.

(f) At Lewis Research Center the preferred ladders shall be fiberglass, for the following reasons: (1) Ladders are generally used in close proximity to electrical equipment; thus it is necessary for the worker to be isolated from ground by a nonconductive material. (2) Fiberglass ladders are nearly maintenance free, requiring little or no manpower for inspection, repair, and refinishing.

(g) All hooks, slings, and other fittings shall be the correct size for the work to be done and shall have sufficient strength to safely sustain the loads imposed on them. If this cannot be adhered to, a waiver from the Safety Assurance Office must be obtained.

> NOTE: All hooks shall be approved safety hooks rather than the open-throat type.

(h) Prior to using equipment, employees should visually inspect it for defects.

(i) Where socketing is done, it shall be done only with zinc (spelter) and only by the manufacturer of the wire rope.

(j) Where swaged or compressed fittings are used, they shall be applied only by the manufacturer.

(k) The hook on any lifting device shall not be painted since this restricts visual or dye penetration inspection.

Torque wrenches.—This section applies when the **tightness** of a threaded fastener is specified as a **torque value** (such as inch-pounds or foot-pounds) on engineering drawings or in specific written instructions from the design engineer. Although the direct elongation (micrometer), angular turn-of-nut, and other methods of controlling the tension in a threaded fastener are also commonly referred to as "torquing," a **torque value** is specified only when a precision torque wrench is to be used.

In addition to torque values, the written instructions for which this section applies must contain the tightening sequence and specify either nonlubricated threads or the lubricant for the threads. The instructions must clearly define the conditions for which the torque values were selected. The importance of clarity is that a slight change in one of the conditions may markedly alter the torque-tension relationship and, hence, the tension produced by a given torque. In general, this torquing method utilizes a torque-tension relationship to produce a tension in the fastener, within a relatively narrow range, that makes an effective fastener without overstress. The design engineer will specify the proper lubricant if one is to be used (such as a specific antiseizing compound that may be required to prevent galling of thread materials in high-temperature applications) and the torque value that applies when this compound is used.

Policy: It is Lewis policy that when torque values are specified in the applicable written instruction, a calibrated torque wrench shall be used to tighten the fastener. On defined critical assemblies, torque-calibrated impact or nutrunner wrenches shall **not** be substituted for a precision torque wrench.

Coating the mating surfaces of joints is not permitted. All **joints** are to be assembled uncoated, clean and dry, metal-to-metal (except nonmetallic gasket designs).

For aircraft equipment, torque values shall be those given in the technical orders for the specific aircraft. For equipment other than aircraft, the torque values shall be determined by a design engineer and indicated on the applicable written instruction (maintenance/assembly manual) or drawings. Torque value specifications are required for all critical fasteners, such as rotating couplings, pressure joints, and components subject to high speed or high load vibration, high temperature, or severe temperature variation. Questions concerning torque values for specific fasteners on specific joints shall be resolved by the appropriate design engineer before the fastener is torqued.

Procedure: Before torquing a fastener, verify (1) that components of both the fasteners and the joint are as specified; (2) that there is a specific statement about lubrication of the threads (i.e., either a lubricant is specified, or dry/nonlubricated threads are specified); and (3) that the components of the joint and the fastener are clean. (This means **no** coating on mating surfaces of the joint, **no** paint on face of nuts or bolt heads, **no** burrs, grit, or dirt on threads, etc.—**not** just "as received.")

CAUTION: Torque values depend on

(a) Size, type, fit, and plating of threads

(b) Materials of the joined fastener and pieces

(c) Whether washers are to be used and, if so, whether they are hardened or plain

(d) Whether threads are to be dry or lubricated and, if lubricated, what lubrication is to be used

(e) Whether a nut or a bolt is to be used

During rundown of the fastener to the snug position, verify that the turning effort matches the specified fit. As an example, if a Class-2 fit (free running fit) is specified, the assembler should be able to easily finger-turn the fasteners during rundown.

Torque the fastener to the value indicated on the applicable written instruction. Check carefully that the torque units of the instruction match those of the wrench. The use of an adapter or extension on a torque wrench will result in a greater torque application than indicated by the dial or setting. Thus, when an adapter or extension is used, the torque reading or setting must be determined as follows:

$$\text{Torque reading or setting} = \text{Specified torque (actual)} \times \frac{\text{Length of wrench}}{\text{Length of wrench} + \text{Effective extension length}}$$

<u>Rules</u>: When a tightening sequence is specified for a contiguous group of fasteners

(a) Torque the fasteners in that sequence at reduced torque (10 percent below specification). Follow that initial torquing sequence with a second at 5 percent below specification before administering the final torquing sequence at the specified level. Exercise care so as not to exceed the specified value.

(b) Do not attempt to use a torque wrench to tighten a fastener to a higher value than the maximum value shown on the torque wrench indicator or setting.

(c) Sockets must be fully installed on the nut or bolt. Maintaining a slight inload (force holding toward the fastener) on the tool will lessen the chances of damage to the fastener.

(d) Never jerk a torque wrench. Force must be applied slowly to obtain an accurate indication of the torque being applied to the fastener.

(e) Torque readings must be taken only while tightening the fastener. Do **not** over-tighten and then loosen to the desired torque value.

(f) All torque wrenches must be calibrated by authorized personnel at least **annually** to compensate for wear. The wrenches shall be identified by serial number and tagged with the calibration date; they shall not be used after the void date shown on the wrench. In order to ensure that all wrenches are available for annual calibration, each one is to be returned to the tool crib at the end of each shift. Torque wrenches shall not be kept in tool boxes, supply cabinets, and such.

(g) Torque wrenches are precision tools; they must not be subjected to abuse or misuse. Recalibration is required if the wrench is dropped. (In general, dial or click types are not as durable as beam memory torque wrenches.)

(h) When the torque specification calls for use of a torque-calibrated impact or nut-runner wrench, care shall be taken to ensure the proper preparation of the air (clean, dry, well-controlled pressure, proper lubrication) before it enters the pneumatic tool.

(i) Inspection and/or verification of torquing of high-speed coupling fasteners and fasteners designated as critical shall be logged for the record.

<u>Portable lifting devices and hoists.</u>—This section outlines the safety rules and responsibilities that pertain to shop personnel in the use of portable or fixed lifting equipment.

<u>Responsibility</u>: The Lewis organization responsible for the inspection and maintenance of the subject equipment is the Mechanical Support Branch of the Facilities Operation Division. This organization is to be apprised of any purchase of new, or replacement, lifting equipment. See Chapter 20 of this Manual for comprehensive information on all lifting devices.

<u>Operating rules</u>: Only employees authorized by a supervisor and instructed in the safe operation of cranes or hoists shall be permitted to operate such equipment. The following rules apply:

(a) Hoisting equipment shall be visually inspected before each use and shall be removed from service for testing if weakness is apparent or suspected.

(b) A minimum of two persons shall be required to use overhead cranes to move large or heavy loads, one to operate the crane controls and one to direct and guide the load.

(c) Loads shall never exceed the rated capacity of the hoisting equipment.

(d) Suspended loads shall never be left unattended.

(e) Employees shall not ride loads, hooks, and slings suspended from hoisting equipment. The use of an approved bosun's chair is permissible.

(f) Loads shall be carried as near to ground level as possible and shall never be carried over the heads of personnel. All personnel shall stand clear of suspended loads.

(g) The cable shall never be run out to a length exceeding the perpendicular distance between the floor and the crane cable drum. At least two full wraps of the lifting cable shall remain on the drum at all times.

Powered industrial trucks.—This section establishes minimum safety standards for the construction, use, operation, and maintenance of powered industrial trucks, but does not apply to vehicles intended primarily for earth moving or over-the-road hauling.

Requirements: The following requirements apply to the equipment, modification, maintenance, and repair of industrial trucks powered by electric motors or internal combustion engines:

(a) Warning devices—Each truck or tractor, except motorized hand trucks, shall be equipped with a warning device, automatic or manual, to alert personnel that the vehicle is moving backward. In some cases, when there is danger to personnel, warning devices may be installed to operate when the truck is moving forward and backward. Such devices may be warning lights (rotating or flashing yellow) or warning sounds (bell or horn).

(b) Overhead protection—Per ANSI/ASME B56.1, industrial trucks shall be equipped with a driver's overhead guard whenever industrial truck operations expose the operator to the danger of falling objects.

(c) Load backrest extension—If the load will present a potential hazard when the mast is in a position of rearward tilt, the industrial truck shall be equipped with a backrest extension.

(d) Fueling (such as gasoline and diesel fuel)—Industrial trucks shall be refueled at locations specifically designed and designated for the purpose. All refueling shall be in accordance with the NFPA 30.

(e) Liquefied petroleum gas fuel—Storage and handling of liquefied petroleum gas (LP gas) shall be in accordance with the standards of "Storage and Handling of Liquefied Petroleum Gases" (NFPA 58; ANSI Z106.1).

(f) Battery charging—Battery charging shall take place in an area designated for that purpose. Facilities shall provide

- Flushing (neutralizing spilled electrolyte) equipment

- Fire protection

- Adequate ventilation for dispersal of fumes from gassing batteries

- A posted sign reading, "Caution—No Smoking or Open Flames"

(g) Portable fire extinguisher—One portable fire extinguisher for use on Classes B and C fires shall be kept on each vehicle.

(h) Name plates—A name plate shall be placed and maintained in a legible condition. The name plate should include the name of the manufacturer, model, serial number, type, weight, operation and maintenance instructions, rated load capacity, and information about alterations, changes, and use of attachments.

(i) Type designations—Each truck shall meet the requirements to be designated as a specific type under the NFPA 505 system. The designations under this system are

- D diesel
- E electrical
- G gasoline
- LP liquefied petroleum gas
- DS diesel powered truck with additional safeguards to the exhaust, fuel, and electrical systems
- DY diesel powered truck with all the safeguards of a DS type and with temperature limitation features, but with no electrical equipment, including the ignition
- ES electrically powered unit with additional safeguards to the electrical system to prevent emission of hazardous sparks and to limit surface temperatures
- EE electrically powered units with all the requirements of E and ES units, but with the electric motors and all other electrical equipment completely enclosed
- EX electrically powered units different from E, ES, and EE units in that the electrical fittings are designed and assembled so that the unit can be used in certain atmospheres containing flammable vapors or dust (NFPA 505)
- GS gasoline powered unit with safeguards to the exhaust fuel and electrical system

(j) Markings—Since the use of proper equipment in potentially hazardous areas is essential for the safety and protection of employees and property, trucks approved for use in such areas must be clearly identified and approved by the cognizant Area Safety Committee. Durable markers indicating the type of truck (from the list previously defined) should be applied to each side of the vehicle in a visible but protected location (NFPA 505 and ANSI B56.2).

(k) Conversion from gasoline to LPG fuel—Vehicles approved for gasoline can be converted to LP without approval of the manufacturer, providing that the conversion does not affect safe operation of the vehicle and that it complies with the manufacturer's conversion instructions. LPG vehicles, however, cannot be converted to gasoline fuel, and vehicle upgrading from type G to GS is not currently permitted.

(l) Modifications and additions—Any modification or addition that affects capacity and safe operation shall be performed by the manufacturer or with his written approval, or with approval of the Safety Assurance Office. The name plate must reflect the change.

(m) Maintenance practices—All replacement parts shall be equivalent to those used in the original design, insofar as safety is concerned. A scheduled preventive maintenance and inspection system shall be followed.

General rules: Only authorized and properly instructed employees shall operate powered industrial trucks; each of these employees must have a U.S. Government motor vehicle operator's identification card, or equivalent in the case of contractors, for the type of powered industrial vehicle being operated. In addition, the following rules and procedures apply:

(a) Industrial trucks shall be operated within rated capacity.

(b) Before an industrial truck is operated, the truck shall be verified to be properly equipped for the work and location.

(c) Faulty equipment shall not be operated. The operator shall check the equipment before use, and any defect shall be immediately reported to the supervisor.

(d) Repairs and adjustments shall not be made by the operator unless he/she is specifically authorized to do so.

(e) Reckless driving and horseplay shall not be permitted.

(f) Operators shall not allow anyone to stand or walk under elevated loads.

(g) Operators shall not reach through fork uprights for any purpose.

(h) When a forktruck is used to elevate employees, a suitable platform, securely fastened to the forks, shall be provided; the platforms shall include standard personnel guardrails.

(i) Motors shall not be allowed to idle for a long period of time in enclosed or semi-enclosed areas.

(j) Fuel tanks shall not be filled while the motor is running.

(k) Any spillage shall be carefully washed away, and tank caps must be replaced before restarting the motor.

(l) All accidents shall be reported immediately to the supervisor.

(m) When batteries of electric forklifts are being charged, vent caps should be kept in place to avoid electrolyte spray. Care should be taken to ensure that vent caps are functioning.

For other information, contact the Safety Assurance Office.

Operating rules: The following are rules applying to powered industrial vehicles:

(a) Speed limits of 5 mph inside and 15 mph outside the plant buildings, consistent with conditions, shall be observed.

(b) Operators shall keep forks as low as possible when moving them, with or without a load.

(c) Operators shall look in the direction of, and keep a clear view of, the path of travel.

(d) Operators carrying bulky loads that obstruct vision shall always drive in reverse.

(e) Operators moving long lengths of material shall be guided.

(f) Only industrial trucks with pneumatic tires shall be used outside of the buildings.

(g) Industrial trucks specified for road use shall be equipped with head lights, tail lights, stop lights, and a horn.

(h) Operators shall keep to the right, slow down at intersections, sound the horn at blind corners, and come to a complete stop at all plant stop signs.

(i) Passing other vehicles at intersections shall not be permitted.

(j) Operators shall proceed cautiously around corners and on wet, greasy, or rough surfaces.

(k) A distance of at least three truck lengths shall be maintained behind other vehicles or pedestrians.

(l) Operators shall watch for weak floors, inadequate dock plates, and if entering a movable vehicle, shall ascertain that it has been secured.

(m) Driving over loose objects shall be avoided.

(n) Railroad tracks shall be crossed diagonally whenever possible. Forklifts shall not be parked within 8 feet of the railroad tracks.

(o) Any loaded forklift being driven downgrade shall have the load in the rear; on an upgrade the load shall be in front. When descending a grade, the truck shall be kept under control so that it can be brought to an emergency stop. On all grades, the mast shall be tilted back and the forks raised as far as necessary to clear the road surface.

(p) Operators shall avoid making quick starts and sudden stops.

(q) The right-of-way shall be given to ambulances, firetrucks, and other vehicles in emergency situations.

(r) No one but the operator shall ride on industrial trucks during transit. They are built only for one rider—the operator. It is unsafe for anyone to hitch a ride in any manner.

(s) Operators shall keep clear of loading dock edges and watch all clearances and rear-end swing.

(t) No forklift shall be driven onto an elevator without specific authorization. Capacity of the elevator shall not be exceeded.

(u) No forklift shall be parked so as to obstruct aisles, pedestrian zones, fire equipment, electric panel boards, or stairways.

(v) A forklift shall not be left unattended without first lowering the fork to the floor, turning off the engine, setting the hand brake, and placing it in gear.

(w) A forklift shall not be left on an incline unless the brake is set and the wheels properly chocked.

(x) The hoist limit stop shall not be used to stop the hoist.

Loading and unloading procedures: The following rules apply to forklifts:

(a) Operators shall handle only loads that are properly stacked, secured, and/or palletized.

(b) Operators shall spread forks to accommodate load width and always place them as far as possible under the load.

(c) The load shall be kept centered and against the carriage, with the mast tilted back to cradle the load.

(d) Heavy loads shall be lowered or stopped gradually.

(e) Loads shall not be raised or lowered while the vehicle is in motion.

Rules for propane (LP gas) powered trucks: Since propane is a liquefied petroleum gas, ignition of gas that has escaped from improperly maintained fuel connections or that has been released by relief valves on fuel tanks are the greatest potential dangers. Therefore, the following rules must be observed:

(a) When replacing fuel tanks, shut off the tank valve prior to removal and operate the engine until all fuel in the system is consumed. Exercise care in making connections and make sure there are no leaks.

(b) When the truck is not in use, shut off the tank valve and store the vehicle in a designated parking area.

14.5.4 Safe Use of Potentially Hazardous Materials

Transporting materials.—The following are rules for transporting potentially hazardous materials:

(a) Intracenter and intercenter shipment of materials, whether inert or potentially hazardous, shall require a properly processed Shipping Request.

(b) Employees shall not use the interlaboratory mail or the United States mail to move potentially hazardous material (explosive, flammable, or toxic).

(c) When an employee must hand-carry potentially hazardous material in or between buildings, the material shall be taken in approved containers directly, without delay, to the destination.

(d) An employee shall not leave the Center carrying any potentially hazardous material on his person or in a suitcase, briefcase, or other luggage.

(e) Transporting potentially hazardous materials by private or Government automobiles or in the cabs of Government vehicles is prohibited unless the Safety Officer specifically approves and the material is in approved containers.

(f) Labels shall not be removed from chemical containers unless the containers are empty and have been thoroughly cleaned.

Spraying of paint or combustible liquids.—All spraying of parts or material shall be done in the approved ventilated spray booth or hood. In addition, the following rules apply:

(a) Spray booths and other locations regularly used for spraying paint or combustible liquids shall be ventilated to remove combustible or toxic vapors and to prevent accumulation of explosive or flammable mixtures in the air (29 CFR 1910.107(b)(5)(i) or NFPA 33).

(b) The power ventilation system shall be in operation at all times when paint or combustible liquids are being sprayed and for a reasonable time thereafter to ensure evacuation of all vapors.

(c) Electrical equipment used in conjunction with spray booths shall conform to the "National Electric Code," Class 1, Group D (NFPA 70) and shall be located where **not** subject to deposits of combustible residues.

(d) All electrical equipment used within 20 feet of the opening of the spray booth shall comply with the state code and the "National Electric Code"—Class 1, Group D, Division 2, for outside booth use, or Class 1, Group D.1, for inside booth use.

(e) Spray booths shall be equipped with a National Fire Protection Agency-approved sprinkler system per 29 CFR 1910.107 paragraphs (c)(6)(i) and (h)(12).

(f) Anytime that extensive spraying outside of a spray booth becomes necessary, such work shall be done when the area is clear of all employees not engaged in the spraying operation.

(g) Areas in and around spray booths and hoods shall be kept free of combustible deposits on floors, walls, and ceilings.

(h) Smoking shall not be permitted in any area where spray painting is done.

(i) Only authorized personnel shall be in the spray booth during spray painting.

(j) All personnel shall wear industrial hygienist-approved respirators when spray painting.

(k) All equipment in the spray booth that may generate static electricity shall be grounded.

(l) No source of ignition shall be permitted in any area where combustible materials are being sprayed.

(m) Before any repair to the spray booth is undertaken involving the use of torches, electric arcs, or other sources of ignition, approval shall be obtained from the Safety Assurance Office and Area Safety Committee chairman.

(n) Employees shall not use any solvent for the purpose of cleaning hands or arms unless approval is obtained from the Office of Health Services.

(o) Since highly toxic paints are generally applied under controlled conditions, special precautions shall be taken, and strict adherence to safety practices specified by the manufacturer shall be required.

(p) All paints in the toxic category shall be treated as extremely poisonous and flammable.

(q) Personnel shall wear air-line respirators when they are spraying in confined spaces or within a building. This requires strict adherence to the safety practices specified by the manufacturer.

(r) Spraying shall be done only in approved areas where adequate fire extinguishing equipment is immediately available.

(s) All skin area shall be covered with adequate clothing or protective equipment.

(t) Contaminated clothing shall not be worn.

(u) Employees shall wash thoroughly before eating or smoking.

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Chapter 15. PERSONAL PROTECTIVE EQUIPMENT

Chapter 15. PERSONAL PROTECTIVE EQUIPMENT

15.1 SCOPE

This chapter establishes program requirements and assigns responsibility for the procurement, use, and maintenance of personal protective equipment at the Lewis Research Center Cleveland and Plum Brook Station facilities.

Personal protective equipment shall be provided, used, and maintained in a sanitary and reliable condition wherever it is necessary by reason of hazard due to processes or environment. Activities involving specialized operations may present hazards that are difficult or impossible to completely eliminate or adequately safeguard against by using engineering controls. When a hazard still exists after all practical engineering control measures have been taken, personnel must be provided with adequate protection through the use of personal protective equipment.

15.2 APPLICABILITY

This chapter applies to

(a) All NASA Lewis organizations and employees at both Cleveland and Plum Brook.

(b) Lewis Research Center contractors at Cleveland and Plum Brook, other NASA contractors, non-NASA and noncontractor individuals present at Lewis and Plum Brook, as expressed in the terms of their contracts or agreements with NASA

(c) Center organizational elements, and students, interns, and contractors operating at locations where Lewis has operational jurisdiction

(d) Other government organizational elements who are tenants at the Cleveland Center and Plum Brook Station

15.3 GENERAL REQUIREMENTS

The type of personal protective equipment required for any hazardous operation depends upon the nature and severity of the hazards involved. The Area Supervisor shall request a hazard evaluation by the Office of Environmental Programs so that proper personal protective equipment can be selected. The Office of Environmental Programs will then either select the type of personal protective equipment to be utilized or contact the Safety Assurance Office for assistance in determining the proper kind of personal protective equipment to be used.

Equipment will not be used as a substitute for the elimination of hazardous conditions, but as a supplemental safety measure that is required when engineering controls cannot successfully eliminate or satisfactorily control the hazard.

Supervisory personnel will make every reasonable effort to ensure that the personal protective equipment is being used correctly. Contractors under NASA jurisdiction must provide their own personal protective equipment, as required by the Office of Environmental Programs and the Safety Assurance Office. This equipment must be maintained in reliable condition at all times. The contractor's supervisor will be responsible for ensuring that all contractor personnel, including their subcontractors, properly use and satisfactorily maintain adequate personal protective equipment. No personal protective equipment worn in areas where chemical or asbestos contaminants have been encountered shall be taken to the wearer's residence for cleaning, care, or maintenance without first being decontaminated.

15.4 SPECIFIC REQUIREMENTS

15.4.1 Head Protection

The requirements of 29 CFR 1910.135 apply to any equipment used to protect the head from impact and electrical hazards. All head protection for occupational workers shall protect their heads from impact and penetration by falling and flying objectives and from limited electrical shock and burn. Protective helmets and hard hats shall meet the requirements and specifications established in American National Standard Institute safety requirements for industrial head protection (ANSI Z89.1). Bump caps shall not be used for protection from head hazards, since they do not meet the ANSI requirements.

Head protection shall be required if any aspect of the work environment presents a risk of head injury. Protecting the head may also involve covering or confining long hair where it could become entangled in moving machinery. "Hard Hat" areas will be adequately marked by Area Supervisors. Helmets are classified by ANSI as follows: Class A, which provide a limited voltage resistance and are satisfactory for general service; Class B, which provide high voltage protection; Class C, which offer no voltage protection; and Class D, which satisfy the protection requirements for firefighters' helmets.

All safety hats will be fitted so that there is at least 1-1/2 inches of airspace between the top of the wearer's head and the inside shell of the hat, allowing the suspension to provide adequate cushioning. Chin straps are required where there is a reasonable probability that safety hats may be knocked or blown off. Winter liners should be worn in cold weather applications.

Because safety hats may become damaged, the Area Supervisor must establish a schedule for the regular inspection of safety hats. All components including the shell, suspensions, headbands, and accessories shall be visually inspected for dents, cracks, punctures, and any damage due to impact, rough treatment, or wear that may reduce the degree of safety originally provided by the manufacturer.

The inspection schedule should be implemented in accordance with the manufacturers' recommendations. All defective parts will be replaced immediately, or a replacement safety hat will be issued.

15.4.2 Foot Protection

Per 29 CFR 1910.136, protective footwear with approved metatarsal or toe guards, or both, will be worn by all personnel who are working in areas where heavy materials are handled or who are performing operations that may be hazardous to the feet and/or toes. Safety shoes will be worn by all personnel working in areas that the Safety Assurance Office or the responsible supervisor classifies as hazardous to the feet. Areas hazardous to the feet shall include, but shall not necessarily be limited to, machine shops, garages, construction areas, maintenance shops, electrical shops, stockrooms, industrial areas, and all areas where heavy items are handled or heavy mobile equipment or machinery is being operated.

All safety-toe footwear must meet the requirements and specifications of ANSI Z41.1 for impact and compression strength and must be maintained in reliable condition in order to ensure its adequacy.

The following OSHA Self-Inspection Checklist may be used as a general guideline for supervisors to select the proper type of protective footwear. If supervisors should have any questions concerning the selection of protective footwear after referring to this checklist, they should contact the Safety Assurance Office for classification. To use this checklist, locate the work environment(s) which apply to your situation, review the specific requirements, and indicate whether or not your workplace is in compliance.

15.4.3 Arm and Hand Protection

The general requirements of 29 CFR 1910.132 apply wherever hand and arm protection is needed. Supervisors shall select proper hand protection for employees, based on the type of hazard(s) to be encountered. Since there is no section of 29 CFR 1910 Subpart I specific to hand and arm protection, the requirements in the Code of Federal Regulations that apply to the industries or working conditions encountered shall be referenced. In selecting equipment to protect hands and arms from chemical hazards, electrical hazards, and many other hazards that would require the equipment to have specific performance properties, a qualified representative of the manufacturer shall be consulted.

All arm and hand protection shall be maintained in good, clean condition in accordance with the manufacturer's recommendations. The Area Supervisor will establish a schedule for the regular inspection of arm and hand protectors. Any worn, torn, or otherwise inadequate arm and hand protection shall be properly disposed of and replaced. To accomplish this function and to ensure that no defective equipment is reused after it has been discarded, a procurement system shall be established by the Area Supervisor or his/her designee. Hand protection for chemical use shall be disposed of after use, per recommendation of the Office of Environmental Programs, and shall not be reused.

OSHA Self-Inspection Checklist

Foot Protection

Work environment	Requirements	Yes	No	Action/ comment
General	Provide, require the use of, and maintain in sanitary and reliable condition the protective footwear necessary to protect employees from any hazard that could cause injury or illness			
	Ensure adequacy of employee-owned equipment, including proper maintenance and sanitation			
	Check adequacy of equipment design and construction of footwear for the intended purpose			
	Safety-toe footwear meets requirements and specifications of ANSI Z41.1			
Abrasive blasting	Approved safety shoes worn wherever heavy work is handled			
Asbestos	Provide and require use of special whole body clothing, including shoes, for any employees exposed to airborne concentrations above safe levels			
Carcinogens	Provide protection against carcinogens listed in CFR 1910.1003-1016			
	Provide and require wearing of full body protection, with shoe covers, in regulated areas			
	Employees in maintenance and decontamination wear clean, impervious garments, including boots			
	Provide clean, complete change of protective clothing each day, including foot covers, for animal testing activities			
Construction	Employees in excavating, trenching, and shoring wear suitable foot protection			
Maritime	Safety shoes readily available to all employees and their use encouraged			
	Employees working with paints involving organic coatings, adhesives, and resins dissolved in highly toxic, flammable, and explosive solvents wear rubbers, rubber boots, or rubber-soled shoes without nails			
Open surface tanks	Where the ground is wet under foot, employees wear impervious boots, shoes, rubbers, or wooden-soled shoes			
Sanitation	Provide waterproof footgear or dry places for standing during wet processes			
Sawmills	Provide protective equipment needed for exposure to toxic chemicals			
Welding, cutting, and brazing	Provide fire-resistant leggings, high boots, or equivalent, for heavy work			
Chemical laboratories	Provide safety footwear per 29 CFR 1910.132 for handling of acids or caustics			

15.4.4 Eye and Face Protection

Protective eyewear shall be worn by all individuals in any area where there is a reasonable probability of eye injury. Suitable eye protection shall be provided where machines or operations present the hazard of flying objects, glare, liquids, injurious radiation, chemicals, or a combination of these hazards or any other known hazards. Such areas shall be posted so that they may be recognized as areas requiring proper eye protection. Admittance to these areas shall be prohibited to any individual(s) not wearing the proper eye protection, except in the case of an emergency. Area Supervisors shall ensure compliance.

Eye and face protection shall meet or exceed the ANSI Z87.1 standard "Occupational and Educational Eye and Face Protection Practice." Face shields alone do not provide adequate protection; therefore, they shall be worn over the protective eyewear prescribed for the operation, if a greater degree of face protection is required.

Contact lenses may absorb chemical vapors and other foreign matter, thereby causing eye injury. When the work environment entails exposure to chemical fumes, vapors or splashes, intense heat, molten metals, or a highly particulate atmosphere, contact lens use shall be restricted. In addition, wearing of contact lenses with a respirator in a contaminated atmosphere is prohibited, per 29 CFR 1910.134.

Phototropic or photochromatic lenses shall not be used for indoor industrial applications. They may be used outdoors only, providing the operations do not involve hazardous ultraviolet or infrared radiation.

Employees working with laser operations generating high radiant energy or power shall, preferably, be protected by engineering controls, such as light filters, interlocked shutoffs, beam stops, and the like. During laser operation, safety glasses suitable for the wavelengths of monochromatic light produced shall be worn. The Health Physics Office of the Office of Environmental Programs shall be consulted to determine the type of glasses necessary.

Welding goggles shall be worn by employees performing any welding operations. The following chart may be referenced for shade selection for welding operations, although the choice of a filter shade may be made on the basis of visual acuity and may, therefore, vary considerably from one individual to another.

Eye protectors are a personal item and should be used exclusively by the individual to whom they are issued. They shall be cleaned and disinfected regularly.

All eye and face protection shall be maintained in a clean and reliable condition. Continuous use of dirty or scratched lenses can contribute to eye fatigue and result in accidents. Lenses shall be cleaned as needed. Pitted or scratched lenses must be replaced before the safety eyewear may be used again. Supervisors shall ensure compliance. Safety glasses may be procured through the Office of Health Services.

Selection of Shade Numbers for Welding Filters

[From ANSI Z87.1.]

Operation	Suggested shade number
Shielded metal-arc welding	
Electrodes, ≤5/32 in. (4 mm)	10
Electrodes, 3/16 to 1/4 in. (4.8 to 6.4 mm)	12
Electrodes, > 1/4 in. (6.4 mm)	14
Gas metal-arc welding	
Nonferrous	11
Ferrous	12
Gas tungsten-arc welding	12
Atomic hydrogen welding	12
Carbon-arc welding	14
Torch soldering	2
Torch brazing	3 or 4
Cutting	
Light, <1 in. (25 mm)	3 or 4
Medium, 1 to 6 in. (25 to 150 mm)	4 or 5
Heavy, >6 in. (150 mm)	5 or 6
Gas welding	
Light, <1/8 in. (3.2 mm)	4 or 5
Medium, 1/8 to 1/2 in. (3.2 to 12.7 mm)	5 or 6
Heavy, >1/2 in. (12.7 mm)	6 or 8

15.4.5 Hearing Protection

Hearing protection shall be mandatory whenever sound levels, measured on the A scale of a standard sound level meter at slow response, exceed an 8-hour time-weighted-average (TWA) of 90 decibels (dB). Moreover, a hearing conservation program shall be implemented by the Area Supervisor whenever noise exposures meet or exceed an 8-hour TWA sound level of 85 dBA. Noise shall be monitored by the Industrial Hygiene Office in accordance with the procedures set up in 29 CFR 1910.95. All employees whose exposures equal or exceed the 8-hour TWA of 85 dBA shall be provided with annual audiometric testing conforming to 29 CFR 1910.95 parts (g) and (h). A baseline audiogram shall be administered within the first 6 months of an employee's first exposure at or above the action level.

The Area Supervisor shall provide hearing protectors, at no cost, to all employees exposed to an 8-hour TWA of 85 dBA or greater. The hearing protection must attenuate exposure to a maximum level of 90 dBA from an 8-hour TWA for employees who have **not** experienced a standard threshold shift. For employees who **have** experienced a standard threshold shift, hearing protectors must attenuate employee noise exposure to an 8-hour TWA of 85 dBA or lower.

Attenuation, as it relates to hearing protection, is defined as the decrease in sound pressure level between that of ambient conditions and that perceived by the employee's ear under the hearing protection. The noise reduction rating (NRR) is typically provided on the hearing protection package. However, the NRR values listed should be considered realistic only to the extent that the protectors are properly fitted, worn, and maintained. Research has shown that most hearing protectors attenuate approximately 50 percent of their posted NRR in real life use. Therefore, extra care in fitting and supervising the use of hearing protectors must be exercised, especially when the full NRR is required.

Supervisors shall institute a training program for all employees exposed to noise at or above an 8-hour TWA of 85 dBA. The Area Supervisor shall ensure employee participation in such a program. The training program shall be repeated annually for each employee included in the hearing conservation program. The Industrial Hygiene Office or Safety Assurance Office may be contacted for assistance with the training program.

Records of all noise exposure measurements shall be retained for at least 2 years. Audiometric test records shall be retained for at least the duration of the affected employee's employment. All recordkeeping shall conform to the provisions of 29 CFR 1910.95(m).

As with all personal protective equipment, hearing protectors shall be maintained in a clean, reliable condition. Ear plugs and canal cap-type hearing protectors that are found to be deficient shall be discarded. Enclosure-type and earmuff-type hearing protectors that are found to be deficient shall be repaired or replaced before they may be used again.

15.4.6 Fall Protection

Fall protection such as lifelines, safety belts, and associated equipment must be used in a work environment where the hazards of falling cannot be eliminated by railings, floors, or other means. Area Supervisors must contact the Safety Assurance Office to determine the most appropriate type of fall protection to be used.

Personal lifelines, retrieval lines, body supports, belts, harnesses, and associated equipment shall be used, cared for, and inspected in accordance with the manufacturer's recommendations. Area Supervisors shall ensure compliance.

15.4.7 Respiratory Protection

The Lewis Research Center has a Respiratory Protection Program in place to protect all employees from exposure to harmful concentrations of hazardous or toxic dust, fumes, mists, vapors, gases, or oxygen-deficient atmospheres. The program encompasses all aspects of respiratory protection, from the initial hazard assessment (where the need for a respirator is determined) to the periodic program evaluation process (where the effectiveness of the program is assessed).

<u>Definitions.</u>—The following terms pertain to the Respiratory Protection Program:

(a) Air-purifying respirator. A respirator equipped with cartridges through which the breathing air is filtered by means of the negative pressure created during inspiration.

(b) Atmosphere-supplying respirator. A respirator that supplies breathing air under positive pressure from a clean source to the facepiece.

(c) Competent person. A person within the Office of Environmental Programs who has demonstrated the knowledge and skills necessary to administer certain aspects of the

Lewis Respiratory Protection Program, such as fit-testing, training, hazard assessments, and such.

(d) Dust. Solid particles mechanically generated by handling, crushing, grinding, sawing, rapid impact, or detonation of organic or inorganic materials such as metal, coal, wood, and dirt.

(e) Engineering controls. Methods of controlling employee exposures to toxic materials by modifying the source or reducing the quantity of contaminants released into the workroom environment.

(f) Fit factor. A quantitative measure of the fit of a specific respirator facepiece to a particular individual.

(g) Fit test. A qualitative or quantitative test used to determine if a respirator provides a proper fit for a particular individual.

(h) Fume. Airborne particulate, usually less than 1 micrometer in diameter, formed by the evaporation of solid materials (e.g., metal fume emitted during welding).

(i) Hazard assessment. An evaluation by the Industrial Hygiene Office of the health hazards posed by a specific operation or task.

(j) Mist. Finely divided liquid suspended in air, usually generated by condensation or by dispersion of a liquid (e.g., by splashing, foaming, or atomizing).

(k) Permissible exposure limit (PEL). The airborne concentration of a substance to which most workers may be repeatedly exposed (day after day) without adverse health effects (PEL's are published and enforced as legal standard by the Occupational Safety and Health Administration).

(l) Powered air-purifying respirator (PAPR). An air-purifying respirator that supplies cartridge-filtered breathing air to the facepiece via a battery-operated pump.

(m) Protection factor. The ratio of the ambient airborne concentration of a contaminant to the contaminant concentration inside the facepiece. (A half-mask respirator is believed to provide a minimum protection factor of 10; a full facepiece respirator, a minimum protection factor of 50; and a powered air-purifying respirator, a minimum protection factor of 100.)

(n) Qualitative fit-test. A fit-test method that provides only a pass/fail result (a protection factor is not determined).

(o) Quantitative fit-test. A fit-test method whereby the protection factor of the mask is quantified.

(p) Threshold limit value (TLV). The airborne concentration of a substance to which, and the conditions under which, most workers may be repeatedly exposed (day after day) without adverse health effects. (TLV's are recommendations or guidelines intended for use in the practice of industrial hygiene and intended to be interpreted and applied only by a person trained in industrial hygiene. They are published by the American Conference of Governmental Industrial Hygienists and are not developed for use as legal standards.)

(q) Vapor. A gaseous form of a substance that is normally in the solid or liquid state at standard temperature and pressure.

Responsibilities.—All personnel and their respective supervisors shall be cognizant of and conform to the requirements of the Respiratory Protection Program.

Specific responsibilities are as follows:

(a) Supervisory personnel shall be cognizant of the Respiratory Protection Program as it relates to the needs of their personnel.

(b) The Industrial Hygiene Office (IHO) shall be responsible for the administration, maintenance, and surveillance of the Program.

(c) Personnel participating in the Respiratory Protection Program shall be responsible for complying with the requirements of the Program.

(d) Onsite support service contractors shall administer their own respiratory protection programs, which shall comply with all Occupational Safety and Health Administration (OSHA) regulations as well as those of the Lewis Program.

Companies with support service contractors working in areas under the cognizance of Lewis are responsible for the administration and management of their own respiratory protection program as required by OSHA under 29 CFR 1910.134.

For tasks where Lewis management has determined that it would be more efficient to procure specific industrial hygiene services for contractor and/grantee employees through the IHO, a contractual agreement may be made between Lewis and the contractor.

(e) Co-op students are employees of NASA Lewis and thus are included in the Lewis Respiratory Protection Program.

Student interns are employees of their respective universities and thus are not covered by the Lewis Respiratory Protection Program. However, since the student works at Lewis, the IHO can assist by conducting a hazard assessment of the operations involved.

Respiratory Protection Program.—The Respiratory Protection Program is composed of the following, except where substance-specific OSHA regulations contain more stringent or additional requirements.

Hazard assessment: Prior to the selection and assignment of a respirator, an industrial hygienist or a competent person under the supervision of an industrial hygienist shall perform a hazard evaluation of the task requiring respiratory protection. The evaluation shall include the nature of the hazard, expected or actual levels of exposure, and the duration of the process during which respiratory protection is required.

Whenever possible, air contaminants shall be controlled by accepted engineering control measures (e.g., enclosure, ventilation, wet methods, or substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used.

Medical surveillance: Only persons found to be physically able shall be assigned a task requiring the use of respirators. The Medical Officer (licensed physician) shall determine what health and physical conditions are pertinent and shall perform a pre-placement medical exam. From the pre-placement exam the Medical Officer shall form an opinion regarding the physical ability of the employee to use a respirator and shall send a copy of the written report to the Industrial Hygiene Office for inclusion in the Respiratory Protection Program files.

The employee's medical status shall be reviewed annually by, or under the supervision of, the Medical Officer. In addition, the employee's medical status shall be reviewed whenever the employee experiences difficulty while using the respirator. A written report of each employee's medical status review stating an opinion about the physical ability of the employee to use a respirator shall be forwarded to the Industrial Hygiene Office.

Selection of respirators: Proper selection of respirators shall be made according to 29 CFR 1910.134 and with the guidance of the American National Standards Institute (ANSI) "Practices for Respiratory Protection," Z88.2.

All respirators shall be approved and certified by the National Institute of Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA) under 30 CFR 1 et seq. Air-purifying respirators shall not be used in oxygen-deficient atmospheres or for hazardous chemicals with inadequate warnings, except when written approval is given by an industrial hygienist. Only full-facepiece respirators shall be used in contaminant concentrations that produce eye irritation.

When it is appropriate, employees may choose to use a powered air-purifying respirator (PAPR) in lieu of a negative pressure respirator. However, purchase and use of a PAPR is subject to the approval of the Industrial Hygiene Office.

Disposable dust/mist respirators may be used when appropriate, but such use shall require compliance with all aspects of the Respiratory Protection Program and the written approval of an industrial hygienist.

Protection factors shall be assigned in accordance with current OSHA guidelines and the professional judgement of an industrial hygienist (whichever is more conservative); these factors shall be used for determining the appropriate respirator.

Fit-testing procedures: The employee shall be fitted with a respirator from a selection of respirators that includes at least three sizes of each type of facepiece from at least two different manufacturers. The appropriate respirator shall be chosen by an industrial hygienist or a designated competent person. The choice will be based on the hazard assessment, fit-testing, and comfort. Employees required to wear tight-fitting (a facepiece-to-face seal) air-purifying respirators and tight-fitting atmosphere-supplying respirators shall be fit-tested to ensure that the respirator selected fits the employee well enough to provide adequate protection for the designated task(s). The employee shall be fit-tested prior to the initial use of the respirator and annually thereafter. Employees who use negative pressure respirators for exposure to asbestos-containing materials (ACM) are an exception to this rule. In accordance with 29 CFR 1910.1001, employees exposed to ACM shall be fit-tested at least every 6 months.

The fit-test(s) used shall be in accordance with OSHA and ANSI recommendations and shall be approved by the Industrial Hygiene Office. Both half mask and full facepiece air-purifying respirators may be fit-tested either qualitatively or quantitatively, unless OSHA regulations specify otherwise (e.g., 29 CFR 1910.1001). If a qualitative test is used, the air-purifying respirator may be worn only in atmospheres that do not exceed 10 times the permissible exposure limit (PEL).

If a quantitative fit-test is used, a minimum fit factor of 100 is required for either the half mask or full facepiece respirator (29 CFR 1910.1001(g)). Full facepiece respirators fit-tested quantitatively may be used only in atmospheres that do not exceed 50 times PEL; half masks are restricted to atmosphere not exceeding 10 times PEL.

Tight-fitting atmosphere-supplying respirators may be fit-tested qualitatively or quantitatively. During the fit-test of such a respirator, the facepiece shall be tested without the air-supplying equipment or attachments. If the respirator facepiece passes the test, the assigned protection factor shall be in accordance with that established by OSHA.

Respirator fit-testing records of employees shall be kept for the duration of their employment.

Training program: Prior to first use of a respirator and annually thereafter, the Industrial Hygiene Office shall provide training for each employee required to wear a respirator. Training shall be conducted by an industrial hygienist or a competent person designated by an industrial hygienist. Written records on all employees who use a respirator shall be kept for the duration of their employment. The records shall include names, training dates, and subject areas covered. Training shall cover the respiratory hazards to which an employee may be exposed; the operation, limitations, and capabilities of the selected respirator; inspecting, donning, and removing the respirator; checking the fit and seals when wearing the respirator; practice sufficient to enable the employee to become thoroughly confident and familiar with the use of the respirator; maintenance and storage of the respirator; respirator malfunctions; familiarity with and location of the written Respiratory Protection Program.

All supervisors of employees required to wear respirators shall also be trained annually in respirator selection, use, and maintenance.

Use of respirators: Respirators shall be used only for the tasks for which they have been assigned. If the user intends to use the respirators in unknown atmospheres or in the presence of hazardous materials other than those in the initial hazard assessment, the user shall request a hazard assessment from the Industrial Hygiene Office to ensure proper respiratory protection.

Respirators shall not be worn with anything that would interfere with the facepiece-to-face seal or the good fit. Examples of such include facial hair, facial scars, and headgear that interferes with the seal. Facial hair must be shaved when respirator use is required.

If corrective lenses are to be worn, they shall be worn in such a manner that they do not interfere with the seal of the facepiece. A respirator spectacle kit will be issued for corrective lens use when a full-facepiece respirator is required. Use of contact lenses with a full-facepiece respirator is subject to approval by an industrial hygienist.

Prior to entering the work area, employees shall perform a facepiece seal and valve test (positive and negative-pressure tests) for all negative-pressure respirators.

Should an emergency situation develop in an area where respirator usage is required, such as a spill, fire, explosion, or an atmosphere that is immediately dangerous to life and health (IDLH), the Lewis Fire Department shall respond. Persons other than those affiliated with the Lewis Fire Department shall be evacuated. Emergency use of respirators by NASA employees other than the Lewis Fire Department shall first require the approval of the Industrial Hygiene Office. In fact, all emergency use of respirators shall be administered and controlled by the Industrial Hygiene Office. See "Emergency Use of Respirators."

Maintenance of respirators: Employees are responsible for the maintenance of their personal respirators. Oversight shall be provided by the Industrial Hygiene Office.

Respirators shall be cleaned and disinfected after each use. They shall be stored in a manner that protects them from damage, dust, sunlight, extreme temperatures, excessive moisture, or damaging chemicals.

Respirators shall be inspected before and after each use. Inspections shall include respirator function; tightness of connections; the condition of the facepiece, headstraps, valves, connecting tube and cartridges, canisters, or filters; pliability of rubber parts; and signs of deterioration.

Emergency use respirators shall be inspected and tagged at least monthly in addition to being inspected before and after each use.

All respirators issued by the Industrial Hygiene Office that fail to pass inspection shall be removed from service and returned to the Industrial Hygiene Office for repair or disposal.

Replacement of respirator filters or cartridges shall be in accordance with a schedule established by an industrial hygienist or designated competent person. Replacement filters or cartridges shall be obtained from Stores Stock.

Program evaluation: The Industrial Hygiene Office shall periodically (at least annually) evaluate the effectiveness of the respirator program by conducting work area surveillance. During the review an interview shall be conducted with respirator program participants and their immediate supervisor. Items that shall be evaluated during the annual surveillance shall include wearer acceptance, respirator program operation (respirator selection, training, donning and fit, maintenance, storage, and medical aspects), and appraisal of protection afforded, based on monitoring data. The annual inspections shall be documented. In addition, random inspections shall be conducted to ensure compliance with the program.

Emergency use of respirators: When conditions permit, the Lewis Fire Department, with the support of the Industrial Hygiene Office, shall characterize potentially hazardous atmospheres prior to entry.

Where use of engineering controls is not feasible and emergency use of respiratory protection is required, the Lewis Fire Department shall be the first responders, with the support of the Industrial Hygiene Office. Examples of such situations include unknown atmospheres, confined space entry, oxygen-deficient atmospheres, IDLH atmospheres, or situations where an employee may be overcome by toxic vapors.

Only full facepiece pressure-demand supplied air respirators (SAR) with an auxiliary self-contained air supply or self-contained breathing apparatus (SCBA) may be used in an unknown, or oxygen-deficient IDLH atmosphere. Each SCBA used in IDLH atmospheres or for emergency entry or fire fighting shall be certified for a minimum service life of 30 minutes. SAR's and SCBA's shall be used only by personnel trained in their use and limitations.

The buddy system shall be used; that is, at least one standby person shall be present in a safe area. The standby person shall be properly equipped with a positive-pressure SCBA to assist the respirator wearers in case of emergency, or shall be in direct contact with Lewis Fire Department emergency-response personnel who can assist in an emergency. Communication between the standby person and the respirator wearers shall be maintained at all times. Respirator wearers in IDLH atmospheres shall be equipped with retrieval equipment so that they can be lifted or removed from the area, or equivalent provisions for rescue shall be in place.

Supplied-air quality and use: Compressed air, compressed oxygen, liquid air, and liquid oxygen used for respiration shall be of high quality and conform to OSHA specifications (29 CFR 1910.134(d)).

Identification of filters, cartridges, and canisters: All filters, cartridges, and canisters used in the workplace shall be properly labeled and color coded with a NIOSH/MSHA approval label, as required by 30 CFR 1, before and during their service life.

15.5 SUMMARY

In summary, proper personal protective equipment shall be worn whenever a situation requires its use. If there is any doubt about whether the use of personal protective equipment is required, the Safety Assurance Office or the Office of Environmental Programs shall be contacted to make that determination. When respiratory protection is required because of a hazard, the Office of Environmental Programs, Industrial Hygiene Branch, must approve such use.

All personal protective equipment shall be maintained in a reliable condition. Regular inspection of the equipment is required to ensure its adequacy. Area Supervisors shall be responsible for ensuring proper use and maintenance of their employees' personal protective equipment.

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Chapter 16. CONFINED SPACE ENTRY

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Chapter 16. CONFINED SPACE ENTRY

16.1 SCOPE

This chapter establishes health and safety procedures for entry and work in confined spaces. It is not intended to preclude the use of any additional safety measures that may be needed for a particular situation.

All confined spaces shall be considered immediately dangerous to life and health (IDLH) until proven otherwise.

16.2 DEFINITIONS

(a) Acceptable environmental conditions. Confined space workplace conditions in which uncontrolled hazardous atmospheres are not present, and which include any additional environmental criteria the employer may require for employee entry into a confined space.

(b) Area Supervisor. An individual who is responsible for an area, system, or facility where a confined space is located.

(c) Attendant. An individual stationed outside the confined space, who is trained as required by this chapter and is on the Authorized Personnel Roster, and who monitors the authorized entrants inside the confined space.

(d) Authorized entrant. An individual who is trained as required by this chapter and is on the Authorized Personnel Roster as being qualified to enter a confined space.

(e) Authorized Personnel Roster. The list of qualified individuals at Lewis, both contractor and NASA personnel, who have been trained as required by this chapter. Attendants, authorized entrants, and Entry Supervisors are listed on this roster.

(f) Blanking or blinding. The absolute closure of a pipe, line, or duct by fastening across its bore a solid plate that completely covers the bore. The plate shall be capable of withstanding the maximum upstream pressure from the pipe, line, or duct.

(g) Ceiling concentration. The concentration of a toxic agent beyond which an employee shall not be exposed during any part of the work. Ceiling concentrations are listed in 29 CFR 1910, Subpart Z.

(h) Confined space. A space with one or more of the following characteristics:

- Limited or restricted access for entry or exit, making it difficult for someone to enter or to rescue an individual in case of emergency

- A design that is incompatible with continuous worker occupancy

- Unfavorable natural ventilation or, perhaps, known or potentially hazardous atmospheres (e.g., oxygen-deficient, oxygen-enriched, flammable, explosive, toxic, or otherwise harmful)

- Conditions conducive to engulfment, entrapment, or other serious safety or health hazards

Confined spaces include, but are not limited to, storage tanks, pits, vats, reaction vessels, ventilation and exhaust ducts, boilers, silos, sewers, manholes, tunnels, trenches, underground utility vaults, and pipelines

(i) Confined Space Operating Checklist. A checklist, written by the Area Supervisor, that lists safety precautions for a specific confined space.

(j) Double block and bleed. The closure of a line, duct, or pipe by locking and tagging a drain or vent that is open to the atmosphere in the line between two locked-closed valves.

(k) Emergency. Any occurrence (including failure of hazard controls or monitoring equipment) or event(s) internal or external to the confined space that could endanger entrants.

(l) Engulfment. The surrounding and effective capture of a person by a liquid or finely divided solid substance.

(m) Entry. The act by which a person intentionally passes through an opening into a confined space and any ensuing work in that space. Entry is considered to have taken place as soon as the entrant's face breaks the plane of an opening into the confined space.

(n) Entry Permit (NASA Form C-199). A printed document which authorizes a specific entry by personnel into a confined space. The document shall reference a Confined Space Operating Checklist.

(o) Entry Supervisor. The designated individual who has direct charge of the entry into the confined space. The Entry Supervisor must be trained as required by this chapter and listed on the Authorized Personnel Roster.

(p) Hazardous atmosphere. An atmosphere that exposes employees to a risk of death, incapacitation, injury, or acute illness from one of the following causes:

- A flammable gas, vapor, or mist in excess of 10 percent of the lower explosive limit (LEL)

- An airborne combustible dust at a concentration that obscures vision at a distance of 5 feet or less

- An atmospheric oxygen concentration below 19.5 percent or above 22 percent

- An atmospheric concentration of any substance for which exposure could occur in excess of its permissible exposure limit (PEL) or threshold limit value (TLV)

- Any atmospheric condition recognized as immediately dangerous to life and health (IDLH)

(q) Immediately dangerous to life and health (IDLH). Any condition that poses an immediate threat of loss of life or that may result in irreversible or immediate-severe health effects, eye damage, or irritation, or that could impair escape from the confined space.

(r) Immediate-severe health effects. Any acute clinical sign(s) of a serious, exposure-related reaction manifested within 72 hours after exposure.

(s) Isolation. A process whereby the confined space and systems within the confined space are removed from service, and completely protected against the inadvertent release of energy or material, by placing them in a zero mechanical state. This includes electrical lockout of all sources of power, mechanical disconnects, blanking or blinding, and double block and bleed systems.

(t) Lower explosive limit (LEL). The minimum concentration (usually expressed in percent by volume at sea level) of a flammable gas or vapor in air that will ignite if an ignition source (sufficient ignition energy) is present.

(u) Oxygen-deficient atmosphere. An oxygen concentration of less than 19.5 percent by volume at normal atmospheric pressure.

(v) Oxygen-enriched atmosphere. An oxygen concentration greater than 22 percent by volume at normal atmospheric pressure.

(w) Permissible exposure limit (PEL). The maximum 8-hour time-weighted-average (TWA) concentration of an airborne contaminant to which an employee may be exposed as specified in 29 CFR 1910, Subpart Z. At no time shall the exposure level exceed the contaminant's ceiling concentration or the short-term exposure limit (STEL) specified in 29 CFR 1910, Subpart Z.

(x) Retrieval line. A line or rope secured at one end to the worker by a chest-waist or full-body harness and at the other end either to a lifting or other retrieval device, or to an anchor point located outside the entry portal.

(y) Short-term exposure limit (STEL). A 15-minute time-weighted-average (TWA) concentration specified in 29 CFR 1910, Subpart Z that shall not be exceeded even if the 8-hour TWA is below the PEL.

(z) Threshold limit value (TLV). The time-weighted-average (TWA) concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed, day after day, without adverse effects.

16.3 APPLICABILITY

This chapter applies to

(a) All NASA Lewis Research Center (Cleveland Center and Plum Brook Station (PBS)) organizations and employees

(b) All Lewis contractors, other NASA contractors, non-NASA and non-contractor individuals present at Lewis in accordance with the terms of their contracts or agreements with NASA

(c) Other government organizational elements who are tenants at Lewis or any other locations under Lewis jurisdiction

16.4 RESPONSIBILITIES

16.4.1 Entrants

Responsibilities of the entrants are to

(a) Recognize potential hazards.

(b) Complete training per Section 16.8.1 of this chapter.

(c) Initial the Entry Permit to verify that the requirements of the permit have been read and that they allow for safe entry into the confined space.

(d) Isolate the confined space and the equipment within the confined space as required by the Confined Space Operating Checklist.

(e) Study the entrance and exit routes and ensure that entrance into and exit from the confined space can be made readily.

(f) Use personal protective equipment properly if required by the Entry Permit and/or the Confined Space Operating Checklist.

(g) Verify that atmospheric tests have been conducted.

(h) Enter the confined space only after ensuring that all the precautions listed on the Entry Permit and Confined Space Operating Checklist have been taken.

(i) Maintain continuous communications with the attendant once inside the confined space.

(j) Exit the space immediately if the attendant orders an evacuation or if danger is perceived.

(k) Notify the attendant prior to a self-initiated evacuation of the space.

16.4.2 Attendants

Responsibilities of the attendants are to

(a) Complete training per Section 16.8.2 of this chapter.

(b) Initial the Entry Permit to verify that the requirements of the permit have been read and that they allow for safe entry into the confined space.

(c) Verify that communications equipment for the attendant and entrant is present and operational.

(d) Verify that communications equipment for summoning rescuers is present and operational.

(e) Monitor the entry of only one confined space at a time.

(f) Monitor the retrieval line, if there is one present.

(g) Recognize potential hazards and monitor activities inside and outside the confined space to ensure that it is safe for the entrants to remain in the confined space.

(h) Remain immediately outside the entrance to the confined space the entire time the confined space is occupied.

(i) Maintain an accurate count of all persons in the confined space as well as the time each entrant spends within the space.

(j) Maintain effective and continuous communication with the entrants while they are within the confined space.

(k) Order entrants to evacuate the confined space immediately if

- A condition is detected that the Entry Permit or Confined Space Operating Checklist forbids
- Symptoms or behavioral effects of chemical or physical exposure are detected
- A situation that could endanger the entrants is detected outside of the confined space
- An uncontrolled hazard within the confined space is detected
- The attendant must leave the workstation

(l) Summon rescue and other emergency aid as soon as it is determined that the entrants must escape from the confined space hazards.

Note: The attendant shall not enter the confined space to rescue entrants.

(m) Warn unauthorized persons away from the confined space if they approach the confined space area.

16.4.3 Entry Supervisors

Entry Supervisors shall

(a) Ensure that the requirements of this chapter have been properly implemented.

(b) Complete training per Section 16.8.3 of this chapter.

(c) Ensure that the entrants and attendants have completed training per Sections 16.8.1 and 16.8.2 of this chapter by verifying that their names appear on the Authorized Personnel Roster.

(d) Properly identify the hazards of the confined space.

(e) Prepare the Entry Permit, and attach a copy of the Confined Space Operating Checklist to the Entry Permit.

(f) Contact the Safety Assurance Office/Plum Brook Management Office to review and approve the Entry Permit.

(g) Ensure that the authorized entrants and attendants read and initial the Entry Permit.

(h) Post the approved Entry Permit in a conspicuous location near the entrance of the confined space.

(i) Use the Confined Space Operating Checklist and the Entry Permit to ensure necessary safety precautions have been taken.

(j) Verify that the confined space and equipment within the confined space have been appropriately isolated per Chapter 9, if required.

(k) Ensure that atmospheric tests have been conducted.

(l) Verify that the required alarms, ventilation equipment, monitoring equipment, communications equipment, and rescue equipment are present, operational, and calibrated.

(m) Ensure that entry operations are consistent with the terms of the Entry Permit and the Confined Space Operating Checklist and that acceptable environmental conditions are present. Sign the Entry Permit to indicate that all the safety measures listed on the Entry Permit and Confined Space Operating Checklist have been taken.

(n) Use appropriate barriers to keep unauthorized persons away from the confined space.

(o) Ensure that the attendant remains outside of the confined space at all times during the entry operations.

(p) Cancel the Entry Permit and terminate entry if acceptable environmental conditions are not present. The Safety Assurance Office/Plum Brook Management Office must then be contacted to determine precautions for future entry.

(q) Take the necessary measures to conclude the entry operation, such as closing off the confined space and canceling the Entry Permit, once the work inside the confined space has been completed.

(r) Forward a copy of the Entry Permit to the Industrial Hygiene Office after the work inside the confined space is completed.

(s) Take appropriate measures to remove unauthorized persons who are in or near the confined space. Contact the Security Branch if necessary.

(t) Report any new or unidentified confined spaces to the Safety Assurance Office/ Plum Brook Management Office.

16.4.4 Rescuers (Lewis Fire Department/Plant Protection Branch)

At Cleveland it is the responsibility of the Lewis Fire Department and at Plum Brook the responsibility of the Plant Protection Branch to

(a) Complete training per Section 16.8.4 of this chapter.

(b) Conduct oxygen content and combustible gas testing.

(c) Perform rescue and emergency operations when summoned.

(d) Use personal protective equipment and rescue equipment properly.

(e) Maintain current certification in basic first aid and cardiopulmonary resuscitation (CPR) skills.

(f) Practice making rescues from confined spaces at least once every 12 months.

16.4.5 Safety Assurance Office/Plum Brook Management Office

Safety Assurance Office/Plum Brook Management Office personnel shall

(a) Complete training per Section 16.8.5 of this chapter.

(b) Determine if an area meets the definition of a confined space per Section 16.2 of this chapter.

(c) Provide assistance to the Area Supervisors in the preparation of the Confined Space Operating Checklist by advising on the potential hazards of the confined space and the necessary precautions for entry.

(d) Evaluate and approve the Confined Space Operating Checklist.

(e) Maintain a file copy of the approved Confined Space Operating Checklists.

(f) Maintain a file copy of the Authorized Personnel Roster.

(g) Review and approve the Entry Permit.

(h) Maintain a file copy of the approved Entry Permit.

(i) Maintain an inventory list of all identified confined spaces.

(j) Audit activities during confined space pre-entry and entry to ensure conformance to this chapter.

(k) Audit the confined space program periodically to ensure compliance to this chapter.

16.4.6 Area Safety Committee

Area Safety Committee members shall

(a) Be aware of the presence of confined spaces in their respective areas and of the hazards of confined spaces.

(b) Report any new or unidentified confined spaces to the Safety Assurance Office/ Plum Brook Management Office.

16.4.7 Area Supervisor/Contract Supervisor

Responsibilities of the Area Supervisor and/or Contract Supervisor are to

(a) Complete training per Section 16.8.6 of this chapter.

(b) Be aware of the presence of confined spaces in their respective buildings and of the hazards of confined spaces.

(c) Develop a written Confined Space Operating Checklist.

(d) Monitor confined spaces so as to detect unauthorized entries.

(e) Report any new or unidentified confined spaces to the Safety Assurance Office/ Plum Brook Management Office.

(f) Notify the Safety Assurance Office/Plum Brook Management Office of any alterations to a confined space so they may ensure that the hazards of the confined space have not been affected.

16.4.8 Industrial Hygiene Office/Plum Brook Management Office

Industrial Hygiene Office/Plum Brook Management Office personnel with confined space program responsibilities shall

(a) Complete training per Section 16.8.7 of this chapter.

(b) Perform testing and monitoring for toxic substances within the confined space, as necessary.

(c) Administer the Respiratory Protection Program when required.

(d) Retain copies of the Entry Permit and any additional atmospheric testing results.

16.4.9 Technical and Administrative Training Branch

The Technical and Administrative Training Branch is responsible for maintaining the Authorized Personnel Roster.

16.4.10 Health Physics Office

The Health Physics Office is responsible for determining the precautions required if any radiation hazards are present.

16.5 PROCEDURES FOR ENTRY INTO A CONFINED SPACE

16.5.1 Prior to Entry

Prior to entry into a confined space, the following provisions shall be met:

(a) The Safety Assurance Office/Plum Brook Management Office has determined that the space meets the definition of a confined space as specified in Section 16.2 of this chapter.

(b) The potential hazards of the confined space and the work to be performed in the confined space have been identified and assessed by the Area Supervisor/Contract Supervisor.

(c) A Confined Space Operating Checklist has been written by the Area Supervisor/Contract Supervisor.

(d) The Safety Assurance Office/Plum Brook Management Office has approved the Confined Space Operating Checklist.

(e) Training of the authorized entrants, attendants, and Entry Supervisors has been completed and documented. Authorized entrants, attendants, and Entry Supervisors are listed on the Authorized Personnel Roster maintained by the Technical and Administrative Training Branch.

(f) An Entry Permit has been completed by the Entry Supervisor. Oxygen content, combustible gas, and other required atmospheric testing have been conducted by the Lewis Fire Department (Cleveland Center)/Plant Protection Branch (PBS) and the Industrial Hygiene Office prior to completion of the Entry Permit, thereby ensuring that appropriate precautions are specified on the Entry Permit and/or the Confined Space Operating Checklist.

(g) The Safety Assurance Office/Plum Brook Management Office has checked the Authorized Personnel Roster to ensure that training of the Entry Supervisor, the authorized entrants, and the attendants listed on the Entry Permit has been completed.

(h) The Safety Assurance Office/Plum Brook Management Office has approved the Entry Permit.

(i) The Entry Supervisor has posted the Entry Permit in a conspicuous location close to the entrance of the confined space. A copy of the approved Entry Permit has been filed in the Entry Supervisor's office and in the Safety Assurance Office/Plum Brook Management Office.

(j) Accidental introduction of hazardous materials, inert gases, dangerous air contamination, air pressure or vacuum into the confined space through interconnecting equipment such as piping, ducts, vents, drains, and such, has been prevented by appropriate means such as disconnecting, blanking, blinding, or double blocking and bleeding. The Entry Supervisor has verified that this has been completed.

(k) To prevent injury to those entering the confined space, all fixed equipment containing moving parts within the confined space has been deenergized and locked and/or tagged out in accordance with Chapter 9 of this Manual. The Entry Supervisor has verified that this has been completed.

(l) Electrical circuits in confined spaces have been deenergized and locked and/or tagged out in accordance with Chapter 9 of this Manual. If electrical integrity of the system must be maintained, proper precautions have been taken to ensure personnel safety. The Entry Supervisor has verified that this has been completed.

(m) The Entry Supervisor has verified the completion of atmospheric testing.

(n) If necessary, the confined space has been purged and/or ventilated. The Entry Supervisor has verified that this has been completed.

(o) Atmospheric tests have been conducted a second time, if required (after the confined space has been purged and/or ventilated and prior to entry).

(p) The Entry Supervisor has ensured that no source of ignition (such as a flame, arc, or spark) nor source of static electricity will be permitted in the confined space until tests have confirmed that the percentage of flammable gas or vapor within the confined space does not exceed 10 percent of the LEL.

(q) The Entry Supervisor has ensured that electrical equipment used inside the confined space is properly insulated and grounded. If the confined space is subject to potential contamination by combustible or flammable vapors, gases, or particulates, the electrical equipment used must be explosion-proof in accordance with Section 500 of the "National Electric Code" (NFPA 70). If hand tools are used, they shall be non-sparking.

(r) The Entry Supervisor has ensured that all hand-held electrical equipment has a ground fault circuit interrupter (4 to 6 milliamps, where possible) at the power source, unless the power source is an ungrounded portable generator, an ungrounded battery source less than 28 volts, or an ungrounded isolation transformer of less than 28 volts.

(s) Provisions have been made by the authorized entrants and attendant for ready access to and exit from the confined space. Emergency egress must be made whenever an evacuation alarm is heard or whenever the attendant signals for an evacuation.

(t) The attendant has verified that communications equipment is present and operational.

(u) The attendant has verified that rescue equipment is present and operational.

(v) The Entry Supervisor has verified that any required alarms (such as for ventilation equipment, low oxygen detectors, etc.) are operational.

(w) The Entry Supervisor and/or the Industrial Hygiene Office and the Lewis Fire Department have verified that monitoring equipment is calibrated, positioned correctly, and operational.

(x) Personal protective equipment has been inspected by the authorized entrants.

(y) The attendant is positioned outside the confined space entrance. The attendant shall keep a log of all the entrants as they go in or exit from the confined space and the time that each entrant spends in the confined space.

The Entry Supervisor is responsible for ensuring that all procedures specified on the Entry Permit and the Confined Space Operating Checklist have been followed prior to entry. If the work procedures described on the Confined Space Operating Checklist or the Entry Permit change, a new Entry Permit shall be completed and approved.

16.5.2 After the First Entry

Immediately after the first authorized entrant has entered the confined space, the following actions shall be performed:

(a) The communication system between the entrant and the attendant shall be tested to confirm its effectiveness.

(b) Continuous communication between the entrant and the attendant shall be maintained.

16.5.3 After Work Is Completed

After completion of the work within the confined space, the following actions shall be performed:

(a) The attendant shall verify via his/her log that all entrants have exited the confined space.

(b) The entrants and Entry Supervisors shall restore the equipment to operational readiness.

(c) The Entry Supervisor shall cancel the Entry Permit and notify the Safety Assurance Office/Plum Brook Management Office and the Area Supervisor that the work has been completed.

16.6 CONFINED SPACE OPERATING CHECKLIST

A written Confined Space Operating Checklist is required for each confined space. The Area Supervisor/Contract Supervisor is responsible for writing the Confined Space Operating Checklist, which shall be specific for each confined space. The Area Supervisor/ Contract Supervisor is encouraged to request assistance from the Safety Assurance Office/Plum Brook Management Office during the preparation of this checklist.

The Safety Assurance Office/Plum Brook Management Office will annually review and approve the Confined Space Operating Checklist, which will include the following sections at a minimum:

(a) Identification number of the Confined Space Operating Checklist (typically this will be the same as the confined space identification number)

(b) Identification number of the confined space (see Sec. 16.10 of this chapter)

(c) Location of the confined space

(d) Description of the confined space

(e) The work performed in the confined space

(f) Any materials or chemicals in the confined space (whether stored in or brought into the space)

(g) All of the potential hazards (based on the defined work activity) of the confined space (see Sec. 16.9 of this chapter). Atmospheric testing of the confined space should be conducted to determine the types of atmospheric hazards present

(h) Types of atmospheric testing and monitoring required (e.g., oxygen level, LEL, toxic gases)

(i) A diagram of the confined space and air sampling locations

(j) Type of equipment located in the confined space and any hazards of the equipment

(k) Isolating procedures (see Ch. 9)

(l) Types of barriers and signs required (see Sec. 16.10 of this chapter)

(m) Personal protective equipment required (see Ch. 15)

(n) Ventilation equipment required and procedures for its use (see Sec. 16.13 of this chapter)

(o) Communications equipment required and procedures for its use (see Sec. 16.14 of this chapter)

(p) Rescue equipment required and procedures for its use (see Sec. 16.15 of this chapter)

(q) Completion procedures (see Sec. 16.16 of this chapter)

16.7 CONFINED SPACE ENTRY PERMIT

Entry into a confined space will be by permit only. The Entry Permit (NASA Form C-199) is an authorization and approval form that specifies the confined space identification number and the type of work to be done within the space. The Entry Permit certifies that all known hazards have been evaluated by a qualified person and that the necessary protective measures have been recommended to ensure the safety of the authorized entrants.

An Entry Permit is required for each entry into a confined space. The Entry Supervisor is responsible for applying for an Entry Permit. A copy of an Entry Permit is shown in the appendix.

The Safety Assurance Office/Plum Brook Management Office is responsible for reviewing and approving the Entry Permit, and for establishing an expiration date for the Entry Permit. The permit typically will be valid for a maximum of two weeks; however, for some routine maintenance procedures, the Safety Assurance Office/Plum Brook Management Office may extend the expiration date to a maximum of 1 year.

If any of the conditions specified on the Entry Permit change or if the nature of the work to be performed in the confined space changes, a new Entry Permit must be completed and approved.

16.8 TRAINING REQUIREMENTS

Training shall familiarize authorized personel with the following:

(a) The types of confined spaces found at Lewis and Plum Brook Station

(b) The physical and chemical hazards involved and the signs and symptoms of exposure to these hazards (per Lewis' Hazard Communication program), the need for atmospheric testing, and the appropriate methods of fire protection

(c) Entry and exit procedures

(d) Cleaning, purging, and ventilation

(e) Isolation and lockout methods per this Manual, Chapter 9

(f) Personal protective equipment

(g) Responsibilities of the attendant, entrant, Entry Supervisor, Area Supervisor/ Contract Supervisor, Safety Assurance Office, rescuers, and the Industrial Hygiene Office

(h) Communication systems

(i) Rescue and emergency response procedures

(j) The Entry Permit

(k) The Confined Space Operating Checklist

(l) Atmospheric testing and monitoring of the confined space

(m) Basic first aid and CPR

There are different requirements for various groups, as illustrated by the following sections.

16.8.1 Authorized Entrants

Authorized entrants shall complete training requirements (a) through (k) in the preceding list.

16.8.2 Attendants

Attendants shall complete training requirements (a) through (k).

16.8.3 Entry Supervisors

Entry Supervisors shall complete training requirements (a) through (k).

16.8.4 Rescuers (Lewis Fire Department and PBS Plant Protection Branch)

Rescuers shall complete training requirements (a), (b), (g), and (i) through (m).

16.8.5 Safety Assurance Office/Plum Brook Management Office

Employees in the Safety Assurance Office/Plum Brook Management Office with confined space program responsibilities shall complete training requirements (a) through (k).

16.8.6 Area Supervisors/Contract Supervisors

Area Supervisors/Contract Supervisors shall complete training requirements (a) through (k).

16.8.7 Industrial Hygiene Office

Employees of the Industrial Hygiene Office with confined space program responsibilities shall complete training requirements (a), (b), (d), (f), (g), (j), (k), and (l).

Training records shall be documented and submitted to the Technical and Administrative Training Branch, who will maintain the Authorized Personnel Roster of trained people. The Safety Assurance Office shall maintain a file copy of the roster.

16.9 HAZARDS OF CONFINED SPACES

One of the most significant hazards of working in a confined space is the number of problems associated with rescue from the space. Other hazards are summarized in the following sections.

16.9.1 Hazardous Atmospheres

Flammable/oxygen-enriched atmosphere.—A flammable atmosphere is generally due to enrichment with oxygen (which increases the flammability range of combustibles), vaporization of flammable liquids (such as acetylene, butane, propane, hydrogen, methane, natural gas, liquid hydrocarbons, etc.), byproducts of work procedures (such as spray painting or welding), chemical reactions, concentrations of combustible dusts, and desorption of chemicals from inner surfaces of the confined space.

Toxic atmosphere.—A toxic atmosphere can result from a product stored in the confined space, from the operations being performed (such as welding or spray painting), or from chemicals brought into the space (such as cleaning fluids).

Irritant or corrosive atmosphere.—Irritants include primary irritants such as chlorine, acids, and ammonia as well as secondary irritants such as benzene, carbon tetrachloride, and trichloroethane.

Oxygen-deficient (asphyxiating) atmosphere.—The normal atmosphere is composed of approximately 20.9 percent oxygen and 78.1 percent nitrogen. An oxygen level below 19.5 percent can result in oxygen deprivation. A reduced oxygen level may be caused by consumption of the oxygen during chemical reactions (e.g., by combustion in welding, heating, cutting, or brazing or by rusting), by microbial growth, or by the displacement of oxygen by another gas such as argon, helium, nitrogen, or carbon dioxide.

16.9.2 Physical Hazards

General physical hazards.—General physical hazards must be considered when determining appropriate precautions for entry into a confined space. These types of hazards include possible entrapment or engulfment, ladders or scaffolding, surface residues in the confined space, protrusions, baffles, bends in tunnels, and overhead structural members. These types of hazards not only put the worker at risk but also can impede rescue attempts.

Temperature.—Work in hot and cold environments requires the use of protective, insulated clothing. Therefore, in addition to the physical hazards of hot and cold conditions, the worker has added bulk that must be considered when allowing for movement in the confined space and for exit time.

Chemicals.—Some chemicals can be absorbed through the skin. Therefore, personal protective equipment, engineering controls, and appropriate work practices must be used to prevent skin exposure to these chemicals. These chemicals are denoted with an "x" in the "Skin designation" column of table Z-1-A in 29 CFR 1910.1000.

Noise.—Noise problems are typically intensified in confined spaces because the noise can reverberate within the space. Generally, hearing protection is required if the noise level is above 90 decibels for any period of time or above 85 dBA for an 8-hour time-weighted average (per Ch. 15). The increased intensity of the noise within the confined space and/or within the worker's hearing protection can also disrupt the communication between the authorized entrant and the attendant; this should be considered when choosing communications equipment and defining communication procedures as specified in Section 16.14 of this chapter.

The Industrial Hygiene Office/Plum Brook Management Office shall be contacted to recommend proper hearing protection equipment.

Vibration.—Vibration causes added stress to the worker inside the confined space and may decrease his ability to note potentially dangerous situations.

Electrical and mechanical equipment.—If activation of electrical or mechanical equipment could cause injury, each piece of equipment shall be manually isolated to prevent inadvertent activation.

16.9.3 Other Hazards

Vapor leaks.—To prevent vapor leaks, flashover, and other hazards, the confined space shall be completely isolated by blanking or disconnecting pipes.

Radiation.—The Health Physics Office shall be contacted if there is any radiation hazard.

Communication problems.—In some confined spaces, visual contact between the entrant and attendant is not possible. If visual monitoring of the entrant is not possible, voice or alarm-activated types of communication systems shall be used.

Inadequate illumination.—Suitable, approved illumination is required to provide sufficient visibility for the work being done in the confined space.

Entry and exit limitations.—Entry and exit time can significantly affect the potential hazard of the confined space. Consideration for the following must be made: access to the entrance of the confined space, number and size of the openings, barriers within the space, occupancy load, time required to exit the space in case of an emergency, and time required to rescue injured entrants.

16.10 IDENTIFICATION OF CONFINED SPACES

Area Supervisors are responsible for identifying confined spaces. The Safety Assurance Office/Plum Brook Management Office shall be notified whenever a new confined space is identified. If a confined space is altered, the Area Supervisor must notify the Safety Assurance Office/Plum Brook Management Office, who will determine if any of the hazards have changed.

The Safety Assurance Office/Plum Brook Management Office will maintain a list of identified confined spaces and their hazards. Each confined space will be identified by a unique identification number assigned by the Safety Assurance Office/Plum Brook Management Office. The Lewis Fire Department/Plant Protection Branch (PBS) and the Industrial Hygiene Office will receive a copy of this list.

The Area Supervisor shall obtain a sign (via a work request) to identify the confined space and warn employees. The sign will contain such words as "DANGER," "CONFINED SPACE," "ENTRY BY PERMIT ONLY," and "Contact the Safety Office for permit."

The Safety Assurance Office/Plum Brook Management Office will recommend appropriate barricades and/or barriers to prevent unintentional entry into the confined space.

16.11 PERSONAL PROTECTIVE EQUIPMENT

The type of personal protective equipment required shall be specified on the Confined Space Operating Checklist by the Area Supervisor, in accordance with Chapter 15, Personal Protective Equipment. The Safety Assurance Office/Plum Brook Management Office shall then review the Confined Space Operating Checklist to aid supervisors in determining the types of personal protective equipment required. Additional protective equipment may be specified on the Entry Permit if required.

16.11.1 General Personal Protective Equipment

Types of personal protective equipment include eye and face protection, head protection, foot protection, protective clothing, hand protection, and hearing protection. These types of protective equipment and their proper use are described in Chapter 15 of this Manual.

16.11.2 Respiratory Protection

When results of atmospheric monitoring in a confined space prior to entry show the atmosphere to be potentially hazardous to life or health, then the space shall be ventilated to eliminate the hazard. If the hazard cannot be eliminated or reduced to the permissible exposure level (PEL) by mechanical means, the entrants shall wear respiratory protection. The Industrial Hygiene Office/Plum Brook Management Office will determine the proper level of respiratory protection on the basis of the hazard(s) found inside the confined space. The Lewis Respiratory Protection Program shall provide the guidelines for entrants using respiratory protection.

Any changes in the atmosphere inside the confined space shall be reported immediately to the Safety Assurance Office/Plum Brook Management Office and the Industrial Hygiene Office. The situation will be evaluated and respiratory protection changes will be made as required.

16.11.3 Additional Safety Equipment

The combination of a body harness and/or safety belt with an attached lifeline shall be used when rescue may be contraindicated because of fire, limited exitways, or other hazards; when any failure of ventilation could allow the buildup of toxic or explosive gases; or when the atmosphere is immediately dangerous to life and health.

A safety belt with D-rings for attaching to a lifeline may be used when the confined space does not pose an immediate threat to life. If the exit opening is less than 18 inches, a shoulder type harness should be used.

If corrosive materials are present, an emergency shower and eyewash unit must be accessible within 100 feet of the confined space opening (per ANSI Z 358.1).

16.12 TESTING AND MONITORING PROCEDURES

Entry into a confined space shall be prohibited until the atmosphere has been tested for oxygen content, flammability, and toxic materials. The oxygen content must be determined by appropriate testing prior to measuring the flammability. Oxygen content and flammability tests shall be conducted by the Lewis Fire Department at the Cleveland Center or by the Plant Protection Branch at Plum Brook. Testing for toxic materials shall be conducted by the Industrial Hygiene Office.

In a typical test, proceed as follows:

(a) Conduct atmospheric testing near the opening of the confined space prior to opening the accessway to the confined space.

(b) Open the accessway to the confined space.

(c) From outside of the confined space, test the entry area and the area where the task will be performed. Obtain enough samples to be representative of the atmosphere within the confined space. Typically this will require sampling at all levels (top, middle, and bottom) of the confined space.

(d) Purge and/or ventilate the confined space, if necessary.

(e) Test the atmosphere again as described in step (c).

Note: Testing must be conducted before each entry.

If the individual conducting air testing must enter the confined space in order to complete the atmospheric testing, the individual shall wear Level-1 respiratory protective equipment as well as a combination of a body harness (and/or safety belt) and an attached lifeline.

The Industrial Hygiene Office and the Safety Assurance Office/Plum Brook Management Office, on the basis of the hazards in the confined space and the work being performed within the space, will determine if continuous air monitoring must be conducted. If welding or painting is being done, continuous air monitoring should be conducted. The Entry Supervisor or entrant may also request continuous air monitoring.

Testing and monitoring equipment shall be calibrated in accordance with the manufacturer's guidelines. A record of each calibration shall be filed and be available for inspection for 3 years.

16.13 VENTILATION EQUIPMENT AND PROCEDURES

Employees may not be exposed to air contaminants in concentrations in excess of those specified in 29 CFR 1910, Subpart Z; therefore, it is frequently necessary to purge and ventilate the confined space prior to entry. The type of ventilation used can be general ventilation or local exhaust ventilation. Depending on the nature of the confined space and the contaminants, continuous ventilation may be required. If acceptable levels of oxygen and contaminants are maintained for three consecutive tests at 5-minute intervals, continuous ventilation is probably not required. If toxic atmospheres are produced as part of the work procedures, such as welding or painting, then continuous ventilation is required. Local exhaust ventilation may be provided when general ventilation is not effective because of restrictions in the confined space or when high concentrations of contaminants are present in the workers' breathing zones.

For entries when continuous ventilation is required, air flows must be measured before each entry to ensure adequate air flow. If the confined space is categorized as immediately dangerous to life and health (IDLH), audible and/or visual warning devices will be needed to indicate ventilation failure.

Exhaust systems shall be designed so that workers in the surrounding areas are protected from the contaminated air.

When combustible or flammable gases or vapors may be present, ventilation equipment (if required) must be explosion-proof and must comply with NFPA 70, Section 500 of the "National Electric Code" (NEC). In addition, the bonding requirements of NEC Section 250 must be met. When combustible dusts or ignitable fibers or particulates may be present, ventilation equipment must comply with Sections 502 and 503 of the NEC.

Blower controls should be kept at a safe distance from the confined space.

16.14 COMMUNICATIONS EQUIPMENT

The entrants, attendants, Entry Supervisors, and rescuers must be familiar with the communication system being used for each entry.

16.14.1 Communication With Entrant

The attendant shall maintain constant verbal communication with the authorized entrant. If voice communications are inadequate because of noise, distance, personal protective equipment, or other conditions, an alternate communication system such as visual contact, rope signals, radios, light, or other electrical or electronic alarm devices shall be used.

16.14.2 Rescue Communications

The attendant shall have a pre-arranged communication link (radio or immediate access to a telephone) with the Lewis Fire Department/Plant Protection Branch (PBS) in the event of an emergency. The emergency phone number, 911, must be posted at the telephone(s) from which rescue would be summoned. If a telephone is not immediately accessible, an emergency alarm signal device must be kept near the attendant and used to summon rescuers.

16.15 RESCUE AND EMERGENCY EQUIPMENT AND PROCEDURES

The Lewis Fire Department/Plant Protection Branch (PBS) is responsible for rescues from confined spaces and for providing appropriate rescue equipment.

The attendant is **not** responsible for the actual rescue of an injured entrant; he/she must summon the specified rescuers by dialing 911 or by using some other pre-arranged communications method.

If an entry is classified as immediately dangerous to life and health (IDLH), a person certified in first aid and CPR must be in attendance at the confined space during the entry.

16.16 COMPLETION OF WORK IN THE CONFINED SPACE

When the required work is completed within the confined space, the Entry Supervisor is responsible for ensuring that the space is returned to its normal state. This includes verifying that all entrants have exited the space; reinstating equipment to operational readiness; canceling the Entry Permit; and notifying the Safety Assurance Office/Plum Brook Management Office and the Area Supervisor that the work has been completed.

16.17 MEDICAL SURVEILLANCE

Authorized entrants who are required to use respirators must undergo a medical evaluation per 29 CFR 1910.134 (b)(10) and Lewis' Respiratory Protection Program. Authorized entrants must also demonstrate an ability to see and hear warnings.

16.18 RECORDKEEPING

Approved Entry Permits will be retained on file in the Safety Assurance Office/Plum Brook Management Office and the Industrial Hygiene Office.

Training records will be kept on file by the Technical and Administrative Training Branch for a minimum of 3 years.

Calibration records for testing and monitoring equipment will be kept on file by the appropriate organization for a minimum of 3 years.

Results of inspections and audits as described in Section 16.19 of this chapter will be kept on file by the Safety Assurance Office/Plum Brook Management Office for a minimum of 3 years.

Atmospheric testing results will be retained by the Industrial Hygiene Office in accordance with 29 CFR 1910.20.

16.19 INSPECTIONS AND AUDITS

The Safety Assurance Office/Plum Brook Management Office will randomly inspect confined spaces to ensure compliance with this chapter during the pre-entry and entry activities.

The Safety Assurance Office/Plum Brook Management Office will randomly audit monitoring equipment calibration records.

The confined space program will be audited annually by the Safety Assurance Office/Plum Brook Management Office for conformance to this chapter. Audit results will be documented and kept on file in the Safety Assurance Office/Plum Brook Management Office. A copy of the audit results will be submitted to the Area Supervisor.

16.20 APPENDIX—CONFINED SPACE ENTRY PERMIT AND OPERATING CHECKLIST

NASA Lewis Research Center	Confined Space Entry Permit	Date Issued Expires

Location of Confined Space: Identification No.	Check all Expected Hazards:
Description of Work:	Corrosives or Toxics Flammable/Combustible Liq. Hot Equipment Electrical Entrapment Inert Gases/Asphyxiation Moving Parts O2 deficient/O2 Enriched Spark-Producing Operations Spilled Liquids Thermal Stress Other (Specify)
Entry Date: / Entry Time:	
Requester:	
Signature:	

Date:	Org. Code:	Mail Stop:	PAX/PBX:

Personal Protective Gear to be Used: Eye Protection Foot Protection Head Protection Protective Clothing (Specify) Respirator/SCBA (Specify)	Isolation Actions: Lockout/Tagout Procedures Grounding/Bonding Cables Ignition Sources Other (Specify)
Describe Acceptable Environmental Conditions within Confined Space During Entry:	Describe type of Ventilation which will be used, Location, and Procedures:

Describe Lighting Equipment which will be used:
Describe Testing and Monitoring Equipment to be used: (include cal. date) Before Entry / During Entry
Emergency/Rescue Services: In the event of an emergency call the NASA LeRC Fire Department at PABX 911 (in house phone), outside line: 433-2088

Rescue Equipment on Site: Fire Extinguishers (Type ____) Safety Harnesses Life Lines Air Packs SCBA Backup Breathing Supply Extra Sets of PPE Communications Equipment	Communications Equipment: (for operations) Radio Visual Contact Other (Specify) Communications Procedures:

Authorized Entrants:	Initials:
Eligible Attendants:	
Entry Supervisors:	
I certify that all requirements of this Confined Space Entry Permit have been met. Entry Supervisor's Name: Signature: Date:	Permit Approval: Safety Office: Signature: Date:

Atmospheric Testing:	Initial	Follow-Up (Specify time)					
Location:							
Flammability (% of LFL):							
Oxygen Level:							
Toxic Contaminants:							
Dusts:							
Others:							

Remarks:					
Test Performed by:			Test Performed by:		
Date:	Time:	PAX:	Date:	Time:	PAX:

CONFINED SPACE OPERATING CHECKLIST

1. CHECKLIST NO. ______________

2. CONFINED SPACE IDENTIFICATION NUMBER: ________________________

3. LOCATION OF CONFINED SPACE: ________________________________

4. DESCRIPTION OF CONFINED SPACE: ______________________________

   ____

5. WORK TYPICALLY PERFORMED IN THE CONFINED SPACE: _____________

   ____

6. MATERIALS OR CHEMICALS STORED OR USED IN THE CONFINED SPACE:

   ____

7. EQUIPMENT LOCATED IN THE CONFINED SPACE: ____________________

   ____

8. CHECK ALL POTENTIAL HAZARDS:

<u>HAZARDOUS ATMOSPHERES</u>

FLAMMABLE
TOXIC
IRRITANT
CORROSIVE
OXYGEN-DEFICIENT
OXYGEN-ENRICHED
OTHER (DESCRIBE)
____

<u>PHYSICAL HAZARDS</u>

TEMPERATURE
CHEMICAL ABSORPTION
NOISE
ENTRAPMENT
VIBRATION
ELECTRICAL/MECHANICAL EQUIPMENT
SPARK-PRODUCING OPERATIONS
SPILLED LIQUIDS
OTHER (DESCRIBE)
____

<u>GENERAL SAFETY HAZARDS</u>

VAPOR LEAKS
PRESSURE
RADIATION
COMMUNICATION DIFFICULTIES
INADEQUATE ILLUMINATION
ENTRY AND EXIT LIMITATIONS
OTHER (DESCRIBE) __________________

9. ATMOSPHERIC TESTING REQUIRED:

TYPE	ACCEPTABLE LEVEL
% OXYGEN	19.5 - 22%
% LEL	10% OF LEL

LIST OTHER TESTING REQUIRED (SUCH AS HYDROGEN SULFIDE, CARBON MONOXIDE, HYDROGEN) AND THE CURRENT PEL OR TLV

_______________ _______________

_______________ _______________

_______________ _______________

10. MAKE A SKETCH OF THE CONFINED SPACE AND AIR SAMPLING LOCATIONS:

COMPLETED

11. SPECIFY OR REFERENCE LOCKOUT PROCEDURES: _________

____

12. BARRIERS AND SIGNS TO BE USED: _________ _________

____

13. DESCRIBE VENTILATION EQUIPMENT AND PROCEDURES:

_______________________________ _________

____

____

14. PERSONAL PROTECTIVE EQUIPMENT: <u>COMPLETED</u>

EYE PROTECTION ____________________ ________

FACE PROTECTION ____________________ ________

HEAD PROTECTION ____________________ ________

FOOT PROTECTION ____________________ ________

PROTECTIVE CLOTHING ____________________ ________

HAND PROTECTION ____________________ ________

HEARING PROTECTION ____________________ ________

RESPIRATORY PROTECTION ____________________ ________

EMERGENCY SHOWER/EYEWASH ____________________ ________

OTHER (DESCRIBE) ____________________ ________

15. COMMUNICATIONS EQUIPMENT (FOR CONTINUOUS COMMUNICATION BETWEEN ATTENDANT AND ENTRANT)

VERBAL

RADIO

VISUAL

OTHER (SPECIFY) ____________________ ________

16. COMMUNICATION EQUIPMENT (FOR SUMMONING RESCUE)

TELEPHONE

RADIO

OTHER (SPECIFY) ________

17. EMERGENCY EQUIPMENT ON SITE:

FIRE EXTINGUISHER (SPECIFY TYPE ________)

SAFETY HARNESS

LIFE LINE ________

16.21 BIBLIOGRAPHY

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NFPA 70, Ch. 2, Sec. 250. National Fire Protection Association. 1990. National Electric Code. Wiring and Protection. Grounding.

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Title 29, Code of Federal Regulations, Pt. 1910, Sub. Z. Occupational Safety and Health Standards. Toxic and Hazardous Substances.

———Sec. 20 et seq. Access to Employee Exposure and Medical Records.

———Sec. 134. Respiratory Protection Requirements for A Minimal Acceptable Program.

———Sec. 1000. Air Contaminants.

Chapter 17. CONSTRUCTION SAFETY

Chapter 17. CONSTRUCTION SAFETY

17.1 SCOPE

This chapter describes policies and safety and health requirements for construction activities at the NASA Lewis Research Center. Construction contractors are contractually responsible for all safety aspects of their work. NASA personnel provide oversight function to ensure contractor compliance.

17.2 DEFINITIONS

(a) Construction. New construction, alterations and repairs, routine institutional maintenance, rehabilitation and modernization, and painting and decorating. Construction may be carried out on buildings, utility systems, site improvements, process piping, facility equipment, and research hardware.

(b) COTR. Contracting Officer's Technical Representative. Most construction COTR's are members of the Facilities Engineering Division (FED) or the Plum Brook Management Office (PBMO). COTR authority for contract oversight is provided by letter of appointment from the Contracting Officer.

17.3 APPLICABILITY

The provisions of this chapter apply to all construction for NASA Lewis at the Cleveland Center and Plum Brook Station. This chapter also applies to supply contracts requiring construction services.

17.4 REQUIREMENTS

Construction safety requirements have been established to protect the life, health, and physical well-being of NASA, support-service-contractor, and construction-contractor personnel during construction; to protect the public from hazards incident to operations of NASA contractors; to prevent contamination of property, supplies, and equipment; and to prevent accidents that might interrupt work, thereby delaying NASA programs and/or negativly affecting NASA property.

Toward that end, the following requirements are set forth:

(a) Each construction contract shall contain provisions that define safety and health requirements.

(b) All construction activities must be performed in a safe and healthful manner under the rules and regulations that govern construction safety; that is, construction contractors shall comply with the following:

- OSHA Standards 29 CFR 1910 and 1926

- Applicable standards and regulations established by the Industrial Commission of Ohio

- This and other appropriate safety and health requirements of the Lewis Safety Manual (LSM) and the Lewis and NASA Management Instructions (LMI's and NMI's), especially Safety Manual Chapters 9, Lockout/Tagout, 15, Personal Protective Equipment, and 16, Confined Space Entry; NMI 8621.1, "Mishap Reporting and Investigating"; and LMI 8710.1, "Lewis Hazard Communication Policy and Responsibilities."

(c) A Safety and Health Plan shall be submitted to the COTR by the construction contractor prior to the initiation of field work. Copies of the Safety and Health Plans are also to be submitted to the Safety Assurance Office and the Office of Environmental Programs. The Safety and Health Plan shall identify hazardous operations related to the intended NASA work, including the use of toxic/hazardous materials, and describe how the contractor intends to protect the life, health, and well-being of NASA and contractor employees as well as Government property and equipment. "Hazardous Waste Operations and Emergency Response" (29 CFR 1910.120) has specific requirements for Safety and Health Plans. The contractor shall provide Material Safety Data Sheets (MSDS) for all hazardous materials brought onsite.

(d) A preconstruction conference shall be held with the construction contractor prior to the initiation of field work. The appropriate Building Managers and personnel from the safety, fire, security, and environmental organizations shall be notified and invited.

(e) NASA shall periodically inspect the contract work site to observe, record, and enforce contractor compliance with safety and health requirements. The inspector's report, documenting the results of the inspection, shall be submitted to the COTR within 24 hours. Any unsafe condition that is found should be addressed immediately by notifying appropriate personnel from the safety, fire, security, and environmental organizations.

17.5 RESPONSIBILITIES

17.5.1 Construction Contractor

The construction contractor is required to

(a) Designate in writing, for each contract, a Safety Manager who will ensure compliance with contract safety and health requirements

(b) Implement health and safety requirements and be held accountable for these matters

(c) Maintain lines of communication with their subcontractors and the COTR, to ensure that contract safety provisions are understood and followed

(d) Coordinate with the COTR all operations that involve safe access to hazardous work areas, shutdowns of mechanical and electrical equipment, testing, and interaction between contractor and NASA operations personnel

(e) Ensure that all contractor and subcontractor personnel view the Lewis Safety video before they are issued badges to start work and that all contractor personnel view the video every 2 years

17.5.2 Contracting Officer's Technical Representative

Responsibilities of the COTR are to

(a) Oversee construction activities, thereby ensuring that construction contractors and their subcontractors comply with safety and health requirements (The COTR has first line authority and responsibility for the enforcement of these requirements.)

(b) Maintain a line of communication with the construction contractor, to ensure proper performance of contract safety provisions

(c) Ensure that a preconstruction conference is scheduled and conducted and that the results are documented

(d) Coordinate with NASA operations personnel, for the safety of construction contractors, all activities involving hazardous work area access, mechanical and electrical equipment shutdowns, and certification or operational testing.

(e) Enlist the support of appropriate Building Managers and personnel from the safety, fire, security, and environmental organizations in ensuring a safe work place and compliance with the Lewis Hazard Communication Program throughout the performance of the contract

(f) Review and approve the construction contractor's Safety and Health Plan prior to the initiation of field work

(g) Arrange for final safety inspections of the completed work areas prior to occupancy

17.5.3 Project Manager

The responsibilities of the Project Manager are to

(a) Identify the safety and health hazards in a construction project and ensure that proper safety and health specifications are incorporated into the construction contract (This may be included in the Project Implementation Plan.)

(b) Make recommendations for handling known hazards of the construction effort, if approved safety/handling procedures are not known to be in force

(c) Participate in the final safety inspection of the work area prior to the completion of the contract and occupancy by personnel

17.6 BIBLIOGRAPHY

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NHB 1700.1. NASA Handbook. 1983. NASA Basic Safety Manual. Ch. 2: Safety Requirements for NASA Contracts and Contractor Operations.

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———Pt. 1926. Safety and Health Regulations for Construction.

Title 48, Code of Federal Regulations, Pt. 52, Sec. 223–3. Hazardous Material Identification and Material Safety Data.

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Chapter 18. EXPLOSIVES AND PYROTECHNICS

Chapter 18. EXPLOSIVES AND PYROTECHNICS

18.1 SCOPE

This chapter sets forth the minimum requirements, both for Government and contractor personnel, for the safe use, handling, and control of explosives at NASA Lewis Research Center (Cleveland and Plum Brook Station).

It provides directives for protecting personnel and property involved in explosive operations at all levels from the hazards of explosives and explosive materials. Such materials include all types of explosives, propellants (liquid and solid), oxidizers, pyrotechnic devices, and toxic chemicals.

18.2 DEFINITIONS AND TERMINOLOGY

(a) Certification. Confirmation that an individual has been trained in the basic knowledge and skills to safely and accurately use a designated explosive and has passed the prescribed physical examination (see Lewis Safety Manual, Ch. 2).

(b) Electroexplosive device (EED). A device in which an explosive is initiated by an electrical signal. The explosive then mechanically initiates other explosives. Exploding bridgewire (EBW) initiators shall be considered EED's of a special class.

(c) Explosive. Any chemical compound, mixture, or device, the primary or common purpose of which is to function by explosion (i.e., with substantially instantaneous release of gas and heat), unless such compound, mixture, or device is otherwise specifically classified by the U.S. Department of Transportation (DOT). Refer to the DOT regulations (49 CFR 500 et seq.) for complete definitions of the DOT classes and their compatibility for transportation.

The following table shows, briefly, the type of potential hazard and some examples of explosives in each of the DOT classes.

Class	Type of potential hazard	Examples of explosives
A	Maximum hazard from detonation	Highly explosive materials such as dynamite, picric acid, blasting caps, detonating primers, and so on
B	Flammable hazard from rapid combustion	Special fireworks, flash powders, and propellants, including smokeless ones
C	Minimum hazard	Manufactured articles containing Class A or Class B components, or both, in restricted quantities

(d) Pyrotechnics. Any combustible or explosive combinations or manufactured articles designed and prepared for the purpose of producing audible or visible effects. These are commonly referred to as fireworks.

18.3 POLICY

It is the policy of Lewis Research Center to administer its operations involving explosives at the Center so as to ensure that they are controlled from acquisition through disposal by qualified personnel. Only individuals who are trained and certified in hazardous operations in accordance with the Lewis Safety Manual, Chapter 2, who understand the potential hazards, and who have acquired the skills necessary to carry out their individual responsibilities safely will be involved in the use and handling of explosives.

18.4 RESPONSIBILITIES

18.4.1 Area Safety Committee

The cognizant Area Safety Committee shall have overall approval authority for a safe system of operating with explosives. The Committee shall require written Standard Operating Procedures (SOP's) or Standard Test Procedures (STP's) and checklists to define proper use, handling, and storage of explosives for the system. A copy of the approved SOP/STP will be forwarded to the Safety Assurance Office. In addition, the requester shall route all Purchase Requests (PR's) for explosives through the Safety Assurance Office and the Hazardous Chemicals Office for approval in accordance with LHB 5120.15, "Preparing and Processing Purchase Requests."

18.4.2 Hazardous Chemicals Office

The Hazardous Chemicals Office shall be the coordinating authority on records of accountability for explosives, from procurement through disposal, in accordance with LMI 5104.3. Records of accountability shall be kept on all types and quantities of explosives.

18.4.3 Safety Assurance Office

The Safety Assurance Office shall review all PR's for explosives, in accordance with LMI 5104.3, and shall ensure the safe use, handling, and storage of explosives.

18.4.4 Procurement Division and Transportation Management Branch

These organizations will ensure that contracts for the purchase of explosives contain instructions to vendors about how to properly describe, package, and transport said items in accordance with 49 CFR and 29 CFR 1910.

18.4.5 Employees

Only essential personnel (those necessary to perform operations) shall be present in areas where explosives are handled, stored, or placed.

The two-person buddy system (see LMI 1704.1) shall be used where explosives are handled so that one person may give assistance to the other if an emergency occurs. The two-person system is not required when the only use of ammunition is for small arms or tools.

18.5 PROCURING EXPLOSIVES

18.5.1 Hazards Assessment Form

A Hazards Assessment Form (NASA C-100b) approved by the chairman of the cognizant Area Safety Committee must accompany every Purchase Request (Form NASA C-100) for explosives. Any Purchase Request for explosives that is not accompanied by an approved NASA C-100 shall not be processed. The requester must arrange for suitable storage for explosives **prior to** forwarding a Purchase Request for them.

Before approving the Hazard Assessment Form (NASA C-100b), the chairman of the cognizant Area Safety Committee, in consultation with the Safety Assurance Office, shall verify that the requested explosive is compatible with and has a net explosive weight (NEW) acceptable by the proposed storage location.

18.5.2 Purchase Request

Every Purchase Request (PR) for explosives shall include this instruction:

"Package shall be boldly marked as follows:

CAUTION—UPON RECEIPT CALL HAZARDOUS CHEMICALS OFFICE AND REQUESTOR (DO NOT OPEN)"

In addition, every PR for explosives shall require an Explosives Description Clause, except when ammunition for small arms or tools is involved. The Explosives Description Clause shall state that the explosives vendor shall provide the following: a sectioned assembly drawing of the device, showing all electrical circuitry and general dimensions; a list of the explosive chemicals involved and the location where they are used; the total weight of the explosives in the individual loads, such as the primer mix and the main charge mix; and a current Material Safety Data Sheet (MSDS).

18.6 SYSTEM SAFETY

In general, explosives, when properly controlled and handled, are safe. However, electrical and magnetic circuits or physical abuse can cause premature firing. To minimize such hazards, a system safety approach to design is essential. The rules listed here are to be followed during design and operation of systems using explosives:

(a) All designs or operations that use explosives must have the prior approval of the cognizant Area Safety Committee. Such approval must be indicated by specific wording on the Safety Permit covering the use of the explosive, its function, and the quantity authorized.

(b) Each situation shall be analyzed by a hazard analysis of the chain of events that may lead to an accident.

(c) Special electrical bridge test equipment for EED's shall be limited to 10 mega amps.

(d) All initiation systems (such as electrical or mechanical) shall be carefully inspected.

(e) Initiating circuits shall be electrically isolated from all other circuits and ground systems, shall be physically isolated as far as possible from power lines and electrical equipment, shall be shielded from electrostatic and electromagnetic interference, and shall have fail-safe logic. Circuit design shall include provisions for isolating and grounding the firing leads at a remote location prior to installing or removing EED's.

(f) Two or more functions or devices shall be required to initiate EED's.

(g) All detailed SOP's and STP's with signoff sheets must be signed by two people (the performing technician and one other person, such as another technician, supervisor, cognizant engineer, or designated safety, reliability, and quality assurance representative).

(h) There shall be approved procedures to cover storage, transportation between storage and use locations, installation, use, and removal of explosives (including backout procedures).

(i) Only personnel on authorized-personnel lists may access/handle explosives. Authorized NASA personnel are to be listed on a QFOL (Qualified Facilities Operators List) indicating extent of authorization.

(j) An annual inspection of all earthed grounds used for explosives safety shall be required.

18.7 OPERATIONS AND HANDLING

Operations that use explosives require a valid Safety Permit and shall be accomplished by approved SOP's or STP's.

Only personnel who are listed on an authorized access roster shall have access to explosives. Of these, only personnel listed as certified handlers of a specific explosive or as certified handlers of general explosives shall be permitted to handle an explosive.

The cognizant Area Safety Committee, after reviewing evidence of contractor personnel certification and ascertaining that such persons know and understand the potential hazards involved and have acquired the skills necessary to handle specific explosives, may authorize the contractor personnel to access and handle explosives. Exception: Authorization for contractor personnel to access and handle ammunition in small arms and tools may be granted after review of certification by the Security Officer and Contracting Officer's Technical Representative, respectively.

Personnel who operate with or handle explosives should note the following:

(a) Smoking is not permitted in areas where explosives are handled or used.

(b) The materials being used and the result intended must be understood prior to beginning work.

(c) Explosives operations are to be conducted only with proper use of approved safety equipment and clothing.

(d) Appropriate warning devices shall be used to alert other persons prior to the start of potentially hazardous operations.

(e) Operations involving EED explosives shall be suspended whenever an electrical storm (thunderstorm) is in the near vicinity; normally, that is within 3 miles of the operation.

(f) Static discharge between personnel, devices, materials, and supporting equipment shall be prevented by bringing all to the same potential.

(g) Radio transmission shall not be permitted in or near EED explosives storage and operation sites. Limiting distances shall be determined for the individual EED's and conditions involved.

(h) Blasting galvanometers and Alinco circuit testers (101-58F6), or other appropriate test devices with output limited to 10 mega amps, shall be used for resistance tests of EED's. Resistance tests shall be made only at an approved location (not in a magazine), and results are to be recorded.

(i) A "NO-VOLTAGE TEST" (10.0 millivolts maximum allowable) shall be made at the connector on each EED firing circuit just prior to hookup to an EED. The measurements shall be made between conductors, and between each conductor and the equipment ground.

(j) EED's, on removal from standard packing, will be placed in and remain in metal or metal-clad containers (for RF shielding) until actual installation. The container shall be prominently marked "EXPLOSIVES" while it contains explosives; the marking shall be removed or covered when the explosives are removed.

18.8 TRANSPORTATION

To ensure that full compliance with DOT regulations is accomplished **prior to** movement, proposed shipments of explosives (including shipments between Cleveland and Plum Brook) shall be brought to the attention of the Lewis Transportation Officer. The

Security Branch and the Lewis Fire Department shall be notified of any shipments within, into, or out of the Lewis Research Center (Cleveland or Plum Brook).

Government-owned vehicles used for transporting explosives shall be specifically approved **for such use** by the Lewis Transportation Officer. Only approved vehicles and equipment, in good condition, shall be used for transportation of explosives. The condition of vehicles shall be verified before each use, in accordance with 49 CFR Subch. C and 29 CFR 1910.109.

Vehicle approval by the Lewis Transportation Officer shall not relieve the operator of responsibility for inspection on the day of use. Before transporting explosives, the operator must ensure that the exhaust, electrical, and braking systems are in first-class condition and that required extinguishers are on board and charged. The operator must also turn off the engine of the vehicle while loading and unloading explosives and while the magazine is open.

Unless a vehicle has been specifically approved for the explosives operation, explosives shall be transported at Lewis by personnel on foot.

18.9 STORAGE, ACCOUNTABILITY, AND DISPOSAL

18.9.1 Storage

There are limitations on where explosives may be stored and on the quantity that may be stored in a given location. The requester of explosives is therefore required to arrange for suitable storage **before** a Purchase Request for explosives is processed.

All explosive materials will be stored in magazines, buildings, or areas designated and cited as explosives storage. Quantity-distance standards applicable to storage of explosives are contained in DOD 6055.9. Approval for overnight and short-term storage deviations shall be in writing from the cognizant Area Safety Committee and the Safety Assurance Office. Long-term storage deviations require advance written approval from NASA Headquarters.

Three general types of explosives storage may be considered by the requester:

<u>The dedicated Lewis Explosives Locker Magazine</u>.—This magazine was established as limited quantity storage for mixed groups of compatible explosives classified as DOD Class 1, Division 3 and Division 4. Total net explosive weight (NEW) of all items in the magazine may not exceed 100 pounds, and because of the limited quantity, class-division rules on quantity-distance may be disregarded. The Lewis Safety Assurance Office has cognizance of the magazine. Access and storage and withdrawal records shall be controlled by the Test Installations Division personnel at the Hangar (Bldg. 4).

<u>Specifically approved magazines</u>.—These magazines may be established and approved for limited quantities of a single type of explosive in each magazine. Examples of such magazines are those for security ammunition and those for tool ammunition. Such magazines shall be locked and under cognizance of a designated individual who will be responsible for control of access and for keeping continuous records of accountability for

the explosives. Specific approval by the Lewis Safety Assurance Office and the cognizant Area Safety Committee is required.

Plum Brook igloo magazines.—These magazines classify as Army igloo magazines meeting the requirements of Chapter 5, DOD 6055.9, when they have been properly prepared for explosives use and when quantity-distance requirements are met. The Plum Brook Management Office has cognizance of these igloos.

18.9.2 Accountability

Only personnel designated on a Qualified Facilities Operators List shall be permitted to place or withdraw explosives at storage locations. They shall enter each placement or withdrawal action on the continuous inventory record at the storage location.

The cognizant authority at each storage location shall ensure that a physical inventory is taken at least semiannually, thereby confirming that storage does not exceed authorization and that utilization records are accurate. A copy of the inventory shall be forwarded to the Safety Assurance Office and the Hazardous Chemicals Office.

18.9.3 Disposal

The Hazardous Chemicals Office and the Fire Department shall be responsible for disposal of Government-owned explosive items that have been used or that are unserviceable or obsolete.

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Chapter 19. VEHICLE AND PEDESTRIAN SAFETY

Chapter 19. VEHICLE AND PEDESTRIAN SAFETY

19.1 SCOPE

This chapter addresses safe practices to be exercised by motor vehicle operators and pedestrians within the confines of Lewis Research Center, which includes the Cleveland Center and Plum Brook Station. The "Ohio State Digest of Motor Laws" was the primary document of reference for this chapter.

19.2 APPLICABILITY

The provisions of this chapter are applicable to all NASA and contractor personnel, whether in a Government- or privately-owned vehicle (POV) or on foot, within the confines of the Cleveland Center or Plum Brook Station.

19.3 RESPONSIBILITIES

19.3.1 NASA and Contractor Employees

Each NASA and contractor employee is responsible for observing Lewis traffic regulations, both as a motor vehicle operator and as a pedestrian.

19.3.2 Security Branch

At Lewis the Security Branch is responsible for ensuring compliance with traffic regulations, for issuing and processing Traffic Violation Notices to those who violate such regulations, and for maintaining a file of all violations and violators. At Plum Brook, this function is the responsibility of the Plant Protection Office.

19.3.3 Supervisory Personnel

NASA supervisors are responsible for counseling employees who violate prescribed regulations and, in consultation with the Employee Labor-Relations Group of the Human Resources Management Division, for imposing penalties when necessary. Contractor supervisors are responsible for counseling their employees who violate prescribed regulations and for imposing penalties when necessary.

19.3.4 Employee Labor-Relations Group

The Employee Labor-Relations Group is responsible for assisting NASA supervisory personnel in imposing penalties on NASA employees when it becomes necessary.

19.3.5 Contracting Officer

In the event contractor supervisory personnel are not responsive to Security Branch notices of violations or when actions prescribed by the contract become necessary, the Contracting Officer will initiate action to penalize contractor personnel in violation of prescribed regulations.

19.3.6 Safety Assurance Office

At Lewis, it is the responsibility of the Safety Assurance Office to specify traffic control devices, parking lot markings, and special parking-instruction signs. At Plum Brook this function is the responsibility of the Plant Protection Office.

19.3.7 Lewis Fire Department

The Fire Department will investigate and complete accident reports for all vehicular and pedestrian accidents that occur at Lewis. At Plum Brook this function is the responsibility of the Plum Brook Management Office.

19.4 MOTORIZED TRAFFIC

19.4.1 Vehicle Equipment Regulations

Vehicle equipment regulations for Lewis and Plum Brook are those of the State of Ohio. Ohio law states: "No person shall drive or move...or knowingly permit to be driven, or moved, on any highway any vehicle or combination of vehicles which is in such unsafe condition as to endanger any person" (Ohio Revised Code 4513.02). Ohio regulations also require that the vehicle operator be physically and mentally unimpaired and have in his/her possession a valid driver's license.

19.4.2 Traffic Laws

In addition to the rules herein, Lewis employees and contractor personnel shall obey applicable Ohio traffic laws when at Lewis or at Plum Brook. Traffic regulations specific to Lewis Research Center are given in this section.

Speed limits.—Unless otherwise posted, speed limits are 25 mph for motorists driving on Center streets; 20 mph for those passing through the gates; and 10 mph for those driving in parking lots.

Parking restrictions.—In certain designated areas, parking is restricted by duration or use.

Short-term parking: Short-term parking areas have been established near some buildings that have significant transient traffic. These areas are clearly posted, and parking durations are specified. Short-term parking areas include the oval drive in front of the Development Engineering Building and the west side of Walcott Road in front of the Research Analysis Center Building.

Visitor-only parking: Visitors are allowed to park on the south side of Stratton Road in front of the Administration Building. No parking is allowed on the north side of Stratton Road.

Long-term parking of POV's: Long-term parking is defined as leaving a POV at the Center beyond the normal assigned tour of duty. This situation typically occurs when an employee is on official travel for one or more days. For various reasons, long-term parking (in excess of 24 hours) at Lewis is restricted to the Hangar parking lot. At Plum Brook, employees should contact the Plant Protection Office for instructions.

Disabled vehicles: Disabled vehicles should be identified by a white cloth attached to the left door while the operator is seeking assistance. The operator also must promptly notify the Lewis Fire Department or the Plum Brook Plant Protection Office.

Safety belts and child restraints.—Ohio's mandatory safety belt usage law requires drivers and front-seat occupants of most passenger vehicles to wear their safety belts whenever they drive or ride on Ohio's roadways. Executive Order 12566, "Safety Belt Use Requirements For Federal Employees," also mandates use of safety belts in Federal vehicles and on Federal property.

Infants and children under 4 years old or weighing less than 40 pounds normally must be protected in special safety restraints whenever they ride in motor vehicles. When children ride in vehicles owned by their parents or legal guardians, or are transported by a preschool or daycare center, they must always ride in child restraints. However, if the vehicle is owned by someone other than the child's parents or guardians and is not being operated by a preschool or daycare center, then children between 1 and 4 years of age may wear seat belts when child restraints are not available. **Children under 1 year old must always ride in a special child restraint.**

Motorcycle and motorized bicycles.—Motorcycle and motorized bicycle (hereafter referred to as motorcycle) operators are required to comply with all traffic laws that apply to four-wheeled vehicles. Operators of motorcycles must possess a valid Motorcycle-Only License or a Motorcycle Endorsement to their valid Ohio driver's license.

Other vehicles.—All trucks, trailers, buses, and slow-moving vehicles are subject to the operating regulations found in the jurisdictional traffic laws. When construction and special purpose functions pose additional problems to the usage of the streets and highways, additional laws regarding them are provided by the Motor Vehicle Code of Ohio. These laws are referenced in the "Ohio State Digest of Motor Laws."

19.4.3 Signs, Signals, and Pavement Markings

Because it is necessary for safe driving, all operators of vehicles should know and be able to explain the meaning and use of the signs, signals, and pavement markings used in the state of Ohio and at the Lewis Research Center.

Signs.—Often, the color and shape of a traffic sign indicates the type of information it conveys. Special information signs remind motorists that they should wear their safety belts or that they are approaching a section of the highway where the speed limit is lower.

Warning signs: Warning signs alert motorists to potentially hazardous conditions on roadways and adjacent areas. Most of these signs retain their traditional yellow color as well as their diamond shape, but on many of the signs, symbols have replaced words.

Service and guide signs: Service signs are white on blue and provide directions to service facilities such as campgrounds, hospitals, and rest areas. Guide signs are white on green and provide directional information to cities, airports, colleges, and other major traffic generators. Guide signs also identify designated bike routes.

Regulatory signs: Regulatory signs regulate movement of traffic. Examples are "STOP," "YIELD," "DO NOT ENTER," "WRONG WAY" and prohibitory (red circle and a slash) signs.

Traffic signals.—Traffic signals in Ohio conform to national standards. The steady yellow arrow signal is a caution sequence for turning traffic. "WALK" and "DON'T WALK" signs work in combination with motor vehicle signals to regulate pedestrian traffic.

Traffic flow pavement markings.—These markings, which are now yellow, indicate the separation of traffic flowing in opposite directions. All broken lines on two-way, two-lane highways permit passing, whereas solid yellow lines indicate that passing is prohibited.

19.4.4 Special Conditions

Drivers must take additional precautions when driving in special conditions, such as at night, during the winter, in fog, and on freeways. Learn to be a defensive driver: be prepared for the mistakes of others.

19.4.5 Emergency Vehicles

Emergency vehicles (safety, security, ambulance, and fire vehicles) responding to an emergency are to be granted the right-of-way by operators of all other vehicles. Emergency vehicles are exempt from parking regulations when they are used in the performance of official duties. Emergency vehicle operators are obligated to drive with due regard for the safety of all persons and property.

19.5 PEDESTRIAN TRAFFIC

Traffic safety is just as much a matter of concern for the pedestrian as for motor vehicle drivers. Under the Motor Vehicle Laws of Ohio, the pedestrian has definite rights as well as certain duties and responsibilities in traffic. Knowledge of traffic laws is the pedestrian's best protection in traffic, that is, his/her best defense against death or injury from an accident.

19.6 ENFORCEMENT OF REGULATIONS

19.6.1 Authority of Security Force

All persons within the Lewis Research Center premises must comply with any lawful order, signal, or direction given by any member of the security force in relation to the movement of traffic or parking of vehicles.

19.6.2 Processing of Traffic Violation Notices

Federal employees.—Federal employees who have violated traffic regulation(s) are cited for the violation in the following manner:

(a) Upon determining that a traffic regulation has been violated, the member of the security force making the determination completes Section 1 of the Traffic Violation Notice (NASA Form C-48). The card copy is attached to the violator's vehicle or handed to the violator personally. Remaining copies are processed by the Security Branch or the Plum Brook Management Office.

(b) After Section 2 of NASA Form C-48 has been completed, the original is sent to the violator's supervisor for appropriate corrective or administrative action. The supervisor completes Section 3 of the NASA Form C-48, indicating specific action taken. Both the supervisor and employee sign the form and forward it, along with the required support documentation, to the Security Branch. The action taken must be within the scope of the penalties shown in Section 19.6.3.

Construction and contractor employees.—Construction and support service contractor personnel, in accordance with the clause in their contract entitled "Badges, Passes, Emergencies, Accidents and Traffic Procedures," are also subject to receiving Traffic Violation Notices. Contractor personnel violations are handled as follows:

(a) The member of the security force who determines a traffic regulation has been violated prepares a Traffic Violation Notice (NASA Form C-48). The card copy of the form is attached to the violator's vehicle or is personally handed to the violator. Remaining copies are processed by the Lewis Security Branch or the Plum Brook Management Office. The yellow copy of the form is filed by whichever of these offices is appropriate and the original is forwarded to the violator's employer.

(b) The employer is expected to point out to the employee those conditions of the contract pertaining to traffic regulations and potential penalties. The employer then completes the back side of the NASA Form C-48, indicating action taken (see "Penalties," Sec. 19.6.3), and returns the form to the appropriate NASA office. This should be done within 3 weeks from the date of receipt.

(c) The Lewis Security Branch or Plum Brook Management Office, as appropriate, will maintain records of traffic violations by contractor personnel. These records will be provided to contractors, as necessary, to make the contractor aware of employees who are frequent violators of traffic regulations. In cases of violations where penalties are warranted, the appropriate NASA Contracting Officer will be notified.

19.6.3 Penalties

Parking Violations

First offense	No penalty other than issuance of the Traffic Violation Notice as a matter of record
Second offense in a period within 6 consecutive months of first offense	Oral admonishment
Third and subsequent offenses in a period within 6 consecutive months of second offense	Minimum - oral admonishment Maximum - suspension of driving privileges at Lewis Research Center for up to 15 days

Moving Violations

First offense	Minimum - oral admonishment Maximum - suspension of driving privileges at Lewis Research Center for up to 15 days
Second offense in a period within 12 consecutive months of first offense	Minimum - oral admonishment Maximum - suspension of driving privileges at Lewis Research Center for up to 30 days
Third and subsequent offenses in a period within 12 consecutive months of second offense	Minimum - suspension of driving privileges at Lewis Research Center for up to 30 days Maximum - suspension of driving privileges at Lewis Research Center for up to 60 days

Moving traffic violations may be referred to the U.S. Attorney for prosecution under applicable law. In addition to the penalties set forth in this table, the table of penalties stated in NASA FPM Appendix A of the "Federal Personnel Manual" may be used for more serious offenses.

In all actions taken in accordance with this table, the provisions and terms of the Center-union labor agreements must be observed.

19.7 ACCIDENTS

Motor vehicle accidents occurring on the Lewis Research Center premises and involving property damage or personal injury must be reported immediately to the Lewis Fire Department or the Plum Brook Plant Protection Office. Personnel from the appropriate organization will investigate the accident. This requirement applies to accidents involving privately owned and/or official Government vehicles.

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Chapter 20. CRANES AND LIFTING DEVICES

Chapter 20. CRANES AND LIFTING DEVICES

20.1 SCOPE

This chapter describes general safe practices relating to all overhead cranes and lifting devices. Specific safety considerations are included for all the various types of lifting systems and components located at the Lewis Cleveland Center.

20.2 APPLICABILITY

The provisions of this chapter apply to all overhead cranes, mobile cranes, hoists, personnel-lifting devices, and slings or lifting fixtures located at the Cleveland Center and Plum Brook Station.

20.3 RESPONSIBILITIES

All personnel at Lewis who design, fabricate, construct, maintain, repair, and operate overhead cranes and lifting devices are responsible for understanding this chapter and conforming to its practices and provisions.

20.3.1 Facilities Operations Division

The Facilities Operations Division is responsible for the maintenance, inspection, and testing of and record keeping for all NASA-owned lifting devices and equipment at Lewis.

20.3.2 Plum Brook Management Office

The Plum Brook Management Office is responsible for the maintenance, inspection, and testing of and record keeping for all NASA-owned lifting devices and equipment at Plum Brook Station.

20.4 GENERAL SAFETY REQUIREMENTS

The design, fabrication, installation, maintenance, repair, inspection, and testing of overhead crane and hoist systems and lifting devices shall be done in accordance with the regulations and procedures of the "Occupational Safety and Health Standards," 29 CFR 1910, Subpart N; the American National Standards Institute (ANSI); and the Crane Manufacturers Association of America, Inc. (CMAA).

20.5 SPECIFIC SAFETY REQUIREMENTS

20.5.1 Overhead Crane and Hoist Systems

Testing.—Three types of tests are required for all overhead crane and hoist systems: proof load tests, rated load tests, and operational tests. The proof load and operational tests shall be performed prior to first use of new, reinstalled, or existing cranes that have had repairs, alterations, or modifications to components involved in the lifting or holding capability of that crane. The rated load and operational tests shall be performed every 4 years. All load tests shall be witnessed by a designated representative of the Lewis Facilities Operations Division or the Plum Brook Management Office, as appropriate.

In the proof load test, the test load for overhead cranes and hoists shall not be more than 125 percent of the rated load unless otherwise recommended by the manufacturer. Test loads for mobile cranes shall not exceed 110 percent of the rated load at any selected working radius.

Tagging.—Following the load test, all cranes and hoists shall be given a permanently affixed tag with an identity number, the date of the last load test, and the date of the next scheduled rated load test.

Emergency cutoff switch.—All overhead cranes must be equipped with an emergency cutoff switch or disconnect located in the immediate vicinity of the operating crane. The cutoff switch or disconnect shall be plainly identified, and personnel operating the crane shall know the exact location of the switch or disconnect.

Markings.—The rated capacity of the crane or hoist shall be plainly marked on each side of the crane or hoist. The markings are to be clearly visible from the floor level.

Operation.—Safe operation of an overhead crane or hoist requires the following:

Training: Only personnel having the required training and the authorization of the supervisor shall be permitted to operate the lifting equipment. Training requirements are outlined in Chapter 2 of this Manual.

Inspection: Prior to first use each day or shift, the operator of the crane or hoist shall visually inspect it for mechanical soundness and shall perform a functional integrity test (i.e., ascertain that all equipment performs as intended). If anything questionable is found, the unit should be removed from service.

Proper load: The operator shall never pick up a load in excess of the rated capacity marked on the unit.

Correct load movement: The load should never be picked up with a side pull; it should be kept as near to the ground as practical. No one should ever be allowed to ride the hook or load, and a suspended load should never be left unattended.

When operating a crane or hoist with a wire rope, the operator should never lay the hook on the floor, thereby creating a slack condition. Furthermore, when picking up or lowering the load, the operator should maintain at least two full wraps of rope on the hoist drum at all times.

20.5.2 Lifting Devices

Description.—This section applies to slings, linkage mechanisms, and structural members (e.g., spreader beams) that extend between a lifting hook on a crane or hoist and the object being lifted.

Purchase of lifting devices.—All purchase requests for lifting devices shall be routed for approval through the Facilities Operations Division at the Cleveland Center or the Plum Brook Management Office at Plum Brook. Identification and specification requirements will be assigned, and when the lifting devices are received, they will be inspected for conformance to those requirements.

Testing.—Two tests are required for lifting devices:

Proof load test: Prior to first use, all new, extensively modified, repaired, or altered lifting devices shall undergo a proof load test at 2.0 times the rated capacity (or for natural- or synthetic-fiber rope slings, at 1.0 times the rated capacity). Proof load tests performed by the manufacturer are acceptable if the necessary test certification papers or tags are provided.

Periodic load test: All lifting devices shall undergo a periodic load test once every 4 years at 1.25 times the rated capacity (for natural- or synthetic-fiber rope slings, 1.0 times the rated capacity).

Tagging.—Following the load test, all lifting devices shall be given a permanently affixed tag with an identity number, the rated capacity (in pounds), the date and proof load applied (in tons), the date of the last periodic load test (when applicable), and the date of the next scheduled load test.

Operation.—Safe operation of slings and other lifting devices requires

Inspection: Prior to first use, the operator shall check slings or other devices for defects such as cracks, deformations, gouges, galling, kinks, crushes, corrosion, and excessive wear. Slings that appear to be damaged shall be removed from service. The user shall verify that the weight of the load is within the rated capacity of the sling and that the tag indicates a load test date not more than 4 years past.

Safe practices: Kinks, loops, or twists in the legs of slings should be avoided. The sling must be lifted slowly to avoid shock-loading it, and any sharp corners in contact with the sling shall be padded to minimize damage to it. A sling must never be pulled from under the load when the load is resting on it.

20.5.3 Personnel-Lifting Devices

Description.—This section applies to crane- or hoist-supported devices that are intended to raise or lower personnel; it does not apply to elevators or ground-supported personnel lifts such as manlifts, aerial devices, scissor lifts, and so on.

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Chapter 21. MISHAP REPORTING AND ACCIDENT INVESTIGATION

21.1 SCOPE

This chapter sets forth the policy and procedures for emergency notification about, investigation of, and reporting on mishaps that occur during Lewis operations and in which NASA or contractor personnel, the public, and/or NASA property are involved.

21.2 APPLICABILITY

The provisions of this chapter are applicable to the Cleveland Center and Plum Brook Station.

21.3 AUTHORITY

The authority for this chapter derives from NHB 1700.1(Vol. 1-A), the "NASA Basic Safety Manual," and NMI 8621.1, "Mishap Reporting and Investigating."

21.4 POLICY

Lewis Research Center policy requires that employees promptly report any mishap that occurs, including fire, explosion, natural disaster, equipment or test failure, plant, vehicle, or aircraft accident, environmental or other incident, and close calls. When a mishap is reported, the procedures specified herein are to be followed for responding to the emergency, securing the mishap area, and initiating a reporting sequence to Center and NASA Headquarters personnel.

21.5 DEFINITIONS

For the purpose of this chapter, a NASA mishap is an unplanned occurrence, event, or anomaly that meets one of the following definitions:

(a) Contractor mishap. An unplanned occurrence, event, or anomaly that may be classed as a Type A, B, or C mishap, an incident, or a mission or test failure that involves Lewis contractor personnel or equipment in support of operations at Lewis. A contractor mishap is normally investigated by the contractor and reviewed by Lewis; however, depending on circumstances, it may be investigated separately by Lewis if the Lewis Safety Officer so decides.

(b) Type A mishap. A mishap causing death or causing damage to or destruction of equipment or property equal to or exceeding $1,000,000. A Type A mishap shall be investigated by an independent board appointed by the appropriate NASA Program or Institutional Associate Administrator, unless such appointment is delegated to the Center Director.

(c) Type B mishap. A mishap resulting in permanent disability to one or more persons, hospitalization of five or more persons, or equipment or property damage equal to or more than $250,000 but less than $1,000,000. A Type B mishap shall be investigated by an independent board (excluding Center Safety Officials) appointed by the chairman of Executive Safety Board or by the Center Director.

(d) Type C mishap. A mishap resulting in equipment or property damage equal to or more than $25,000 but less than $250,000, or causing occupational injury or illness that results in a lost workday or restricted duty. A Type C mishap shall be investigated by the Safety Assurance Office, Area Safety Committee, or an independent division.

(e) Incident. An unplanned occurrence that is less serious than a Type C mishap, but in which a loss greater than $1,000 but less than $25,000 is sustained; or a mishap that results in injury requiring medical treatment beyond first aid, but no lost time. The Lewis Safety Office shall appoint a board to investigate an incident.

(f) Close call. An unplanned occurrence in which there is no injury, no significant (less than $1,000) equipment or property damage, and no interruption to productive work, but which possesses potential for any of the foregoing.

(g) Test failure. Unexpected damage of research hardware, including support test hardware or instrumentation, but no significant test facility damage. Test failures can be minor (e.g., combustor lines erosion), in which case they are to be reported through run reports, or they can be significant (e.g., combustor lines burnout), in which case damage is to be reported directly to the division chief. The Office of Mission Safety and Assurance is to be notified verbally of significant test failures.

(h) Costs. Direct costs of repair, retest, delay, replacement, or recovery of NASA materials, including hours, material, and contract costs but excluding indirect costs of cleanup, investigation, injury, and normal operational delay.

(i) Emergency. A state arising from unforeseen circumstances that requires immediate action to limit or contain a situation (such as fire, natural disaster, equipment failure, plant accident, vehicle accident, aircraft accident, etc.) that threatens injury to people or damage to property.

(j) Environmental incident. A health-related environmental incident including, but not limited to, the following (which may or may not constitute emergencies):

- Mercury spill

- Oil spill

- Release of toxic or other hazardous material that causes, or threatens to cause, concentrations of such materials in air or water to exceed established limits

- Unauthorized releases of toxic or other hazardous materials, or releases of large quantities of other materials, into sanitary, industrial, and/or storm sewer systems

- Any condition that causes, or threatens to cause, an individual to be exposed to excessive noise levels, radiation levels, and such

(k) Mishap Reporting and Corrective Action System (NASA Form 1627). Form used to record information on mishaps, incidents, and close calls. It is a three-part form that should be filled out as completely and as accurately as possible; time restraints for its completion are detailed herein.

(l) Safety Help Line System. A specific channel for NASA Lewis and contractor employees to report any safety concern that is or may become hazardous to personnel, facilities, or equipment at the Cleveland facility or Plum Brook Station. The Safety Help Line is under the supervision of the Safety Assurance Office and can be reached at 433-8848.

21.6 RESPONSIBILITIES

21.6.1 Lewis Employees

Lewis Employees are responsible for reporting any mishap that occurs during Lewis operations, including a close call, if NASA or contractor personnel, the public, and/or NASA property are involved.

21.6.2 Lewis Supervisor

The Lewis supervisor of the activity in which an accident or incident occurs is responsible for

(a) Ensuring immediate notification of emergency personnel (by dialing 911 at either Lewis or Plum Brook) and the Safety Assurance Office. Notification is required for any incident or close call resulting in a potential hazard or risk to personnel even though no personal injury or property damage may have occurred.

(b) Investigating the accident to obtain causal information and then reporting such information to the Safety Assurance Office. Supervisors must provide complete, accurate information in a timely manner on NASA Form 1627, Mishap Reporting and Corrective Action System (MRCAS).

21.6.3 Lewis Safety Officer

The responsibilities of the Lewis Safety Officer are to

(a) Serve as the Center focal point for receiving all oral and written mishap reports and notify the Chief of the Safety Division at NASA Headquarters of such incidents in a timely manner.

(b) Ensure that the policies and procedures for reporting, investigating, and documenting mishaps and for taking corrective action are implemented at the Center

(c) Determine the type of investigation required and who will be involved in the investigation of a mishap. (In the case of lost workday mishaps, incidents, and close calls, the Safety Officer may delegate this responsibility to the SAO.) Different groups of people, depending on the severity of the incident, may be involved in mishap investigations; at a minimum, the immediate supervisor of the injured party or area involved should be included, and the Safety Assurance Office (SAO) should assist. Others who may be involved are trained investigators chosen by the Safety Officer, union representatives, Area Safety Committees, ad hoc committees, or the NASA Headquarters Investigation Board. The addition of other parties to the investigating committee does not relieve the supervisor of the responsibility for submitting NASA Form 1627 in a timely manner.

21.6.4 Safety Assurance Office

The Safety Assurance Office is responsible for

(a) Initiating the investigation process by taking NASA Form 1627 to the supervisor or cognizant Contracting Officer immediately upon notification of a mishap, incident, or close call

(b) Determining the type of investigation in the case of a lost workday mishap, incident, or close call, if requested by the Lewis Safety Officer

(c) Assisting in investigations, when required

(d) Reviewing NASA Form 1627 for errors or omissions and returning it to the submitter for further information, if needed

(e) Maintaining the ADP system that contains the MRCAS reporting system

(f) Compiling the information from NASA Forms 1627 and submitting the data to the Lewis Director and NASA Headquarters

(g) Tracking the corrective actions generated through the Safety Help Line

(h) Providing training in investigative techniques and in processing NASA Forms 1627

(i) Investigating a Type B or C mishap, incidents, or close calls

21.6.5 Director of the Office of Health Services

The Director of the Office of Health Services is responsible for

(a) Investigating all Type C mishaps that result in a lost workday or restricted duty due to illness

(b) Notifying the SAO of all reportable injury incidents and lost workday mishaps of NASA personnel. This notification is to be given immediately so that an investigation may be initiated. The Office of Health Services shall provide any medical information that is pertinent to a mishap investigation and that is within their legal authority to release.

21.6.6 Office of Environmental Programs

The OEP is responsible for investigating health-related environmental incidents and providing support, as required, for mishap investigations.

21.6.7 Area Safety Committee

The cognizant Area Safety Committee is responsible for investigating a Type C mishap, an incident, or a close call, when designated by the Lewis Safety Officer.

21.6.8 Contractors

Contractors are responsible for reporting to the Contracting Officer within 1 working day of the incident any mishap, including a close call, that occurs during operations on the Center. Contractors are also responsible for investigating the accident, as directed by the Contracting Officer, and reporting the results of the investigation to the Contracting Officer. This report shall be made via an accurate NASA Form 1627 completed within 5 working days of the mishap, incident, or close call.

21.6.9 Contracting Officer

The Contracting Officer's responsibilities are to

(a) Immediately notify the SAO of all mishaps, incidents, or close calls involving contractors under his/her authority

(b) Provide the contractor with a NASA Form 1627 and ensure that it is properly completed and returned in a timely manner

(c) Return the completed NASA Form 1627 to the SAO in a timely manner

(d) Obtain for the contractors, as needed, training in proper investigative techniques and in procedures for completing NASA Form 1627.

(e) Initiate corrective actions required to abate any hazardous conditions or actions. This may be done by using the Safety Help Line system and/or any other methods available to the Contracting Officer, as required by a contract.

(f) Assist in a mishap investigation as required by the Safety Officer, the SAO, or any board or committee assembled to investigate the mishap or incident.

21.7 EMERGENCY NOTIFICATION AND RESPONSE PROCEDURE

21.7.1 Mishap Notification

The emergency call system (see the appendix) shall be used to **immediately** report any of the following types of mishaps that constitute an emergency:

(a) Injury to or illness of any person at the Cleveland Center or the Plum Brook Station that requires immediate attention by medical personnel

(b) Any damage to equipment, buildings, grounds, aircraft, or vehicles caused by

- Fire or explosion
- System malfunction
- Steam or water
- Propellants or gases
- Contractor activity
- Apparent sabotage
- Human error
- Structural failure
- Striking objects

(c) Environmental incidents

(d) Any condition requiring immediate assistance or nonroutine action to prevent bodily injury or minimize property damage or operating problems

Mishaps, incidents, and close calls that do not constitute an emergency are to be communicated to the SAO immediately.

21.7.2 Cleveland Center Emergency Procedures

<u>Reporting an emergency</u>.—Any person at the Cleveland Center who discovers an emergency condition shall, from a safe location, immediately dial 911 on the nearest telephone to report that assistance is needed. The caller shall state his/her name, the location of the emergency, and the type of help needed. The caller should stay on the telephone until released by the dispatcher. If the caller is in the area involved, he/she should also report the emergency locally in accordance with approved local procedures.

<u>Processing and relaying emergency calls</u>.—Upon receipt, emergency calls shall be relayed by the recipient in accordance with the sequence specified in the appendix.

<u>Bodily injury or illness cases</u>.—The emergency response to a report of bodily injury or illness depends on the time period during which the incident occurs and the severity of the injury.

<u>Regular shift</u>: When notified of bodily injury or illness requiring emergency action during the regular shift, the dispatcher at the Fire Station shall direct Fire Department personnel to respond immediately with the ambulance and the emergency equipment truck.

Upon arrival at the emergency site, the emergency medical technicians (EMT's) shall treat the patient and determine whether hospital care or further treatment at the Office of Health Services is required. If hospital care is indicated, the EMT's shall accompany the ambulance to the hospital if conditions permit.

Off shift: When notified of a bodily injury or illness requiring emergency action during off-shift hours, the dispatcher at the Fire Station shall direct the ambulance with two EMT's to the location of the emergency. Then the shift supervisor shall call the Safety Officer, or his/her alternate, at home to report that the ambulance has taken a patient to the hospital.

Life threatening emergencies: If a situation involves a life threatening emergency, the EMT in charge shall contact the Southwest General Hospital Emergency Room and request the services of the hospital STAT team.

Notification of next of kin: The Safety Officer shall notify the next of kin if he/she considers such action necessary. However, if an employee's condition becomes critical, or in the event of death, the Safety Officer shall notify the Chief of the Human Resources Management Division, who, with the advice or assistance of the EASE Program manager, will inform the employee's family. **Employees other than those noted herein shall not notify the next of kin about an injury or death.**

21.7.3 Plum Brook Station Emergency Procedures

Reporting an emergency.—Any person at the Plum Brook Station who discovers an emergency condition should, from a safe location, immediately dial 911 on a NASA phone to report that assistance is needed. The caller shall state his/her name, the location of the emergency, and the type of help needed; the caller shall stay on the telephone until released by the dispatcher. If the caller is in the area involved, he/she shall also report the emergency locally in accordance with approved local procedures.

Processing and relaying emergency calls.—Upon receipt, emergency calls shall be processed and relayed in accordance with the sequence and priority specified in the appendix.

Notification of next of kin.—The Chief of the Plum Brook Management Office determines if next of kin are to be notified of an emergency. **Employees other than those noted herein shall not notify the next of kin about an injury or death.**

21.7.4 Updating Emergency Call Lists

Cleveland Center.—Each person on the emergency call list is responsible for promptly notifying the Safety Assurance Office of any change in telephone number, address, or ability to continue the assignment.

Plum Brook.—Changes in the emergency call list used by the Station Communications Center at the Plum Brook Station must be approved by the Chief of the Plum Brook Management Office or the designated alternate.

21.8 SECURING A MISHAP AREA

During rescue and disaster control efforts, the Chief of the Fire Department, his senior officer, or the Lewis Safety Officer shall serve as the official in charge and take the following actions:

(a) On arrival at the scene, evacuate personnel, provide rescue, firefighting, emergency medical help and other efforts, as appropriate, to control and terminate the emergency condition.

(b) To preserve evidence, secure the area until it is released by the Lewis Safety Officer. Security personnel shall be used, as required, to control access to the area.

(c) Determine the most appropriate type of investigation to initiate.

(d) Obtain names of onsite witnesses.

(e) Request photographs of the mishap scene and supporting sketches, as required.

(f) Diagram the accident area to scale and indicate relative positions of equipment, wreckage, bodies, obstructions, flight path (if applicable), positions of witnesses, and so on.

21.9 MISHAP NOTIFICATION, INVESTIGATION, AND REPORTING

21.9.1 Immediate Notification

Headquarters.—The Lewis Safety Officer must notify the NASA Headquarters Safety Division of all immediately reportable mishaps by using NASA Form 1367, Telephonic Report for a NASA/NASA Contractor Mishap, as soon as information is available and necessary actions have been taken to aid the injured and protect personnel, facilities, and equipment from further loss. During duty hours, a report shall be made to the NASA Headquarters Safety Division, and during nonduty hours to the NASA Headquarters Duty Officer, for the following types of mishaps:

- Type A mishaps
- Type B mishaps
- Mission failures
- Aircraft- or spacecraft-related mishaps and incidents
- Any Type C mishaps or incidents that the Center Director believes may have significant Headquarters interest

Occupational Safety and Health Administration (OSHA).—The NASA Headquarters Safety Division shall notify OSHA (within 48 hours) if a mishap involves a fatality or if five or more NASA employees or a combination of five or more NASA and non-NASA persons are hospitalized. (These are Type A or B mishaps.) This notification does not relieve a contractor of his responsibility to notify OSHA.

Public release of information.—Public release of mishap information and mishap investigation reports is the responsibility of the Lewis Public Information Office. No information is to be released to the news media or the public from any other Center source.

21.9.2 Investigations

Investigations shall be conducted to determine the actual or probable cause(s), to determine appropriate actions for avoiding recurrence, and to document the investigations and lessons learned so that others can learn from the findings. For mishap prevention purposes, the facts learned shall be made available to and discussed with all appropriate employees. Mishap investigations shall be conducted separately from any collateral investigation conducted for the purpose of determining fault or the need for disciplinary action.

21.9.3 Reporting Results of an Investigation

The findings of each mishap investigation, whether by a board, a committee, or an investigating official, must be documented in a report. Type A and B mishap reports require review by the Executive Safety Board and the Center Director prior to being released for distribution. Type C incident and close call reports require review by the Lewis Safety Officer before being released. Reports of test failures require review by the cognizant division chief prior to being released. After the investigation has been completed and the report has been reviewed by the appropriate authority, the original report and all investigative findings and materials shall be released to the Lewis Safety Officer for permanent records storage.

Schedule.—Type A and B mishap reports shall be forwarded to the investigation board appointing official for review and approval within 60 days of the mishap. Within 75 days of the mishap, the appointing official shall forward 20 copies of the report to the Director of the Safety Division at NASA Headquarters. Along with the report, he/she shall send an implementation plan that includes the corrective actions to be taken in response to the recommendations, the assigned responsibility, and the schedule for closeout; a summary (not more than five pages) for the Public Affairs Division; and a "Lessons Learned" (not more than two pages) to be distributed for mishap prevention purposes at NASA installations. In unusual circumstances additional time may be granted by the appointing official. In such cases, the report shall be forwarded to the Director of the Safety Division at NASA Headquarters within 15 days after receipt by the appointing official.

Report content.—Board reports must be in the format specified by NASA Form 1388, Mishap Report Table of Contents. The purpose of the investigation and the associated report is to determine what happened, its cause, and recommended actions to prevent recurrence. The purpose of the investigation is not to establish blame or to determine or assess disciplinary actions.

Type A and B mishap report approval and closeout.—The appointing official for the board of investigation shall approve the report and ensure followup and closeout on all recommendations. The board report and implementation plan, as well as quarterly status reports, shall be provided to the Director of the Safety Division at NASA Headquarters for review and concurrence.

For boards appointed at the field installation, the Director of the Safety Division at NASA Headquarters shall coordinate the implementation of board recommendations and the final closeout with the appropriate Program or Institutional Associate Administrator. On final acceptance of the board report, the board of investigation shall be considered released.

Board reports for type A and B mishaps are not dated until they have been reviewed and accepted by NASA Headquarters. The Chief of the Safety Assurance Office shall furnish the board report date after the NASA Headquarters review is complete. When all actions have been completed, the board appointing official shall certify, in writing, to the Director of the Safety Division at NASA Headquarters that the board report and followup are complete and considered closed.

Type C mishap, incident, or close call.—Reporting procedures for these situations depend on whether or not someone has been injured.

Injury incident: If an incident involves an injury

(a) The Office of Health Services shall notify, in writing, the injured employee's immediate supervisor about any medical assistance rendered. However, if there is a reportable injury, the Office of Health Services shall immediately notify both the SAO and the supervisor in order to initiate an investigation.

(b) The supervisor shall use NASA Form 1627, MRCAS, to gather initial information about the incident and shall complete and return the first page of this form to the SAO within 1 working day of the incident.

(c) The SAO shall explain the use of Form 1627 and evaluate the initial information. The Safety Officer shall then determine the type of investigation required and notify all parties who will be involved in the investigation.

(d) The immediate supervisor of the injured employee shall complete the second page of NASA Form 1627 and return it to the SAO within 5 working days of the mishap. If the supervisor cannot meet the time limit, the SAO **may** grant an extension. Although the SAO is available to assist in the investigation if needed, it is the supervisor's responsibility to complete and return NASA Form 1627 to the SAO.

(e) On completion of the investigation, corrective action may be necessary to eliminate the causes of the incident. If so, all corrective action should be noted in the appropriate place on NASA Form 1627. For potential hazards, the Safety Help Line system is to be used.

Noninjury incident: For a mishap, incident, or close call that does **not** involve an injury

(a) The immediate supervisor should be informed and the SAO notified with NASA Form 1627. For anonymity, the Safety Help Line may be used.

(b) When notified of the mishap, incident, or close call, the SAO shall deliver a NASA Form 1627 to the Area Supervisor, for initial information. The first page of the form, with all required initial information, must be returned to the SAO within 1 day of receipt.

(c) The SAO shall advise the Safety Officer of the severity or potential severity of the mishap, incident, or close call.

(d) The Safety Officer shall determine the type of investigation necessary and initiate the investigation process.

(e) The Area Supervisor shall investigate the mishap, incident, or close call and complete and return the second part of NASA Form 1627 within 5 days of the notification of the occurrence. If the time limit cannot be met, the SAO **may** grant an extension upon request.

(f) On completion of the investigation, corrective action may be necessary to eliminate the causes of the incident. If so, all corrective action should be noted in the appropriate place on NASA Form 1627. For potential hazards, the Safety Help Line system is to be used.

Contractor incident: In the event of a **contractor** incident, injury, accident, mishap, or close call

(a) The contractor's supervisor shall notify the Contracting Officer of the incident.

(b) The Contracting Officer shall notify the SAO of the incident.

(c) The SAO shall provide NASA Form 1627 to the Contracting Officer and provide assistance in investigating the incident.

(d) The Contracting Officer shall provide the information requested on page 1 of NASA Form 1627 and send it to the SAO within 1 day of notification of the incident.

(e) The SAO shall advise the Safety Officer of the severity or potential severity of the incident.

(f) The Safety Officer shall determine the type of investigation to be conducted and initiate the investigation.

(g) The Contracting Officer or the Contracting Officer's Technical Representative and the contractor's supervisor shall investigate the incident, report the results on page 2 of NASA Form 1627, and submit it to the SAO within 5 working days of the incident. If the time limit cannot be met, the SAO **may** grant an extension upon request. The Safety Operations Branch shall be available to assist in any investigation.

(h) On completion of the investigation, corrective action may be necessary to eliminate the causes of the incident. If so, all corrective actions shall be noted in the appropriate place on NASA Form 1627. For potential hazards, the Safety Help Line is to be used.

21.9.4 Environmental Incident Report

The Environmental Incident Report (EIR) is a written summary of an health-related environmental incident; it provides information that can be used to prevent recurrence of the same or similar incidents.

The supervisor in the area where an environmental incident occurs, or the supervisor of the individual(s) involved, shall prepare a preliminary report covering the details of the incident. The report shall be sent to the SAO and the Office of Environmental Programs. It must include the following information:

(a) Date of the incident

(b) Location of the incident

(c) Identity, physical and chemical form, and quantity of material(s) involved

(d) Identity of the person(s) directly involved or affected

(e) Description of the work area

(f) Description of the incident (including diagrams, etc.)

(g) Immediate action taken to reduce hazards to personnel and property

The final EIR shall be prepared by the Office of Environmental Programs and be based on the supervisor's report and the information developed as a result of any investigations conducted. The completed report shall be submitted to the appropriate Lewis and NASA Headquarters organizations for any further action required.

21.10 APPENDIX—EMERGENCY CALL MATRIX

Key Contacts

		PABX	HOME
Plant Protection			
*	**R. Allen**	3–2085	231–2644
Alt.	Dispatcher	3–2088	N/A
Safety Officer			
*	**L. Wilkins**	3–3019	831–1809
Alt.	M. Dominguez	3–6735	1–353–0788
Public Affairs			
*	**M. Edwards**	3–2899	356–0851
Security			
*	**A. Christian**	3–3035	991–2372
Alt.	R. Mohr	3–3023	349–1593
Environmental			
*	**P. McCallum**	3–8852	899–0811
Alt.	D. Watson	3–3135	779–1972
Chairman ESB			
	S.V. Szabo, Jr.	3–2964	234–5018
Director			
	L.J. Ross	3–2929	871–9585
Chief, SAO			
	F. Greco	3–2650	624–0692
Chief, OMS&A			
	W. Ford	3–2550	729–1517
Chief, Administration			
*	**F. Povinelli**	3–2936	529–1754
Alt.	B. Miller	3–5815	235–4684

* **Prime**
Alt. Alternate

21.11 BIBLIOGRAPHY

NHB 1700.1. NASA Handbook. 1983. NASA Basic Safety Manual. (NASA TM-85234.)

NMI 8621.1, as revised. NASA Management Instructions. Mishap Reporting and Investigating.